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ABSTRACT

This book, addressed to students for their independent use as well as to teachers as a supplement to the standard texts, contains nearly 100 practical science experiments that cover a wide range of subjects at different grade and ability levels. It is designed to involve students in active scientific experimentation, demonstrations, and projects for school and home. Each experiment provides safety precautions, an introduction, procedures, time and materials needed, data tables, and an analysis where applicable. Topics included are: (1) "Earth Science" (which covers such areas as acid rain, pollution, water currents, surface area and erosion, air movement, rocks, and the solar system); (2) "Biology" (covering the formation of a classification key, trees, insects, soil, tidal pools, ecological survey of a marsh, the effect of food supply on fruit fly density, and other topics); (3) "Physical Science/Chemistry" (including testing powers of observation, plant indicators for acids and bases, atmospheric pressure, and salts as neutralizers); and (4) "Physics" (including experiments with uniform motion, gravity, friction, sound waves, circuits, and plane mirrors). Following the experiments, a section called "Our Findings" supplies possible answers to questions cited in the activities, and this is followed by lists giving grade level, supervision required, setting (school or home), and number of participants for each experiment where relevant. Experiments that can be completed in less than an hour are also listed, as are sources for materials and supplies. A list of contributors and an index complete the document. (RT)

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EXPERIMENTS, DEMONSTRATIONS AND PROJECTS FOR SCHOOL AND HOME

SE 050 583

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TABLE OF CONTENTS

I. EARTH SCIENCE

1.001 Does Your Town Have Acid Rain?
James Attison McClanahan

1.002 How Vulnerable are Local Waters to Chemical Pollution?
James Attison McClanahan

1.003 Water Currents
Ross L. Iverson

1.004 Surface Area and Erosion
Marie Z. Sullivan

1.005 Settling Rate and Layering of Various Sized Particles
Alan Schwartz and Dan Griesbach

1.006 Can You Predict the Movement of Air?
Marie Z. Sullivan

1.007 Determining the Geological Age of Rock Samples
Gary L. Stringer

1.008 Licorice Stick Half-Life Dating
Michael G. Pearson

1.009 Reconstruction of an Ancient Environment
Gary L. Stringer

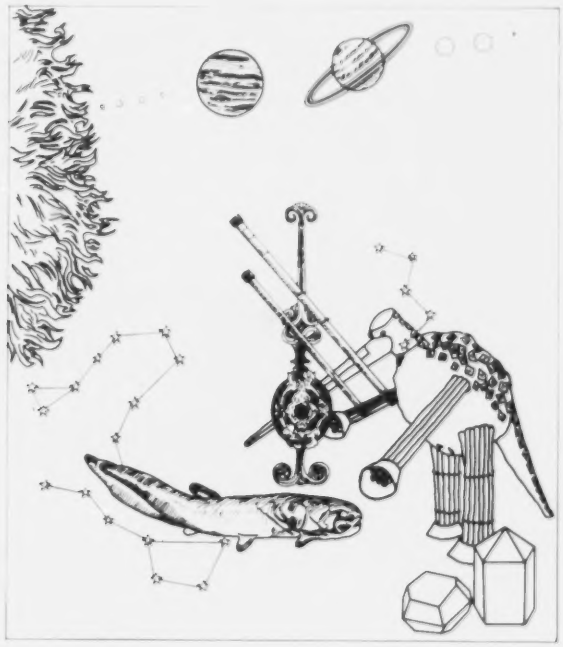
1.010 Make Your Own Aliens
Michael G. Pearson

1.011 Measuring Quartz Crystals
Gary L. Stringer

1.012 Views of the Moon as Seen from Earth
Joyce B. Patton

1.013 Scale Model of Our Solar System
Sue Anne Nothstine

1.014 Skywatch
Ken Schaefer



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II. BIOLOGY

2.001 Shaping Up a Classification Key
Dr. F. H. Shoemaker

2.002 Comparing Trees
Nancy Nowak

2.003 Butterfly Behavior
Barbara E. Rothstein

2.004 What Do Birds Like to Eat?
Lloyd J. Fugate

2.005 Where Do Pill Bugs Like to Live?
Lloyd J. Fugate

2.006 Discovering Tidal Pools
Eileen F. Ferrance

2.007 Ecological Survey of a Marsh
Peggy L. Steffen

2.008 The Effect of Cotyledon Removal on Peanut Embryos
Murray Paton Pendarvis

2.009 The Effect of Soil pH on Plant Growth
Louis A. Ventura

2.010 Study of a Duckweed Population
Ronald J. Cisar

2.011 Effect of Food Supply on Fruit Fly Density
Virgil A. Sestini

2.012 Make Your Own Yogurt
Zoe A. Godby Lightfoot

2.013 Vinegar and the Vinegar Eel
Juliana Texley

2.014 Variations on a Human Face
Donna Mae Jablecki

2.015 The Diving Reflex
Dorothea Allen

2.016 How Good Are Your Taste Buds?
Richard N. Lord, Jr.

2.017 How Are the Senses of Taste and Smell Related?
Susan S. Plati

2.018 The Raw Egg Mystery
Susan S. Plati

2.019 How Simple Is That Sugar? Testing for Monosaccharides
Ed Farrar

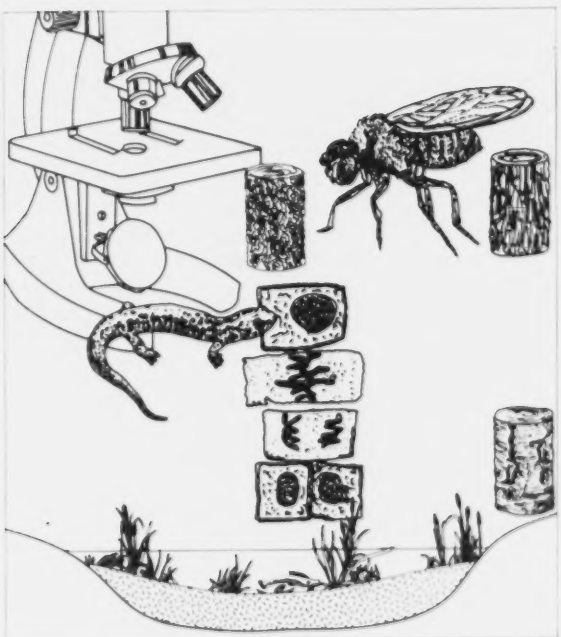
2.020 The Great Fruit Juice Contest
Nevin E. Longenecker

2.021 Dye It Yourself—Naturally!
Richard N. Lord, Jr.

2.022 How Does a Red Leaf Produce Food?
Otis Autry

2.023 Leaves Can Make Photographs
Warren B. Van Camp

2.024 Speeding Up Nature's Green Machine
Chris L. Gentry



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III. PHYSICAL SCIENCE / CHEMISTRY

3.001 Testing Powers of Observation
Jim Cusker

3.002 Seeing Invisible Colors
Edward C. Keller III

3.003 Fingerprinting
Mark T. Allen

3.004 Creating Clay for Testing
JoAnne Dombrowski

3.005 Fast and Fizzy Reactions
Rick Broniec

3.006 Natural Reaction Boosters
C. V. Krishnan

3.007 Products of Combustion
Virgil R. Valente

3.008 What Happens When Water Is Heated?
Greg Schell

3.009 Heat Needed to Melt Ice
Bob D. Suits

3.010 Ice Cream Lab
Linda Preston

3.011 Coffee and Cream Science
Jim Nelson

3.012 The Boltzmann Distribution
Lee Marek

3.013 Bubble Films and Boat Races
Kathleen Scullen

3.014 Metal Floats
Warren B. Van Camp

3.015 The Spectacular Siphon
Courtney W. Willis

3.016 Boiling and Freezing a Balloon
Annabelle L. Lerch

3.017 Gases Have Their Ups and Downs
Carol B. Collins

3.018 Watching Atmospheric Pressure at Work
Michael Minnema and Lois Fruen

3.019 Some Salts Can be Neutralizers
Mary Alice Kubovy

3.020 Flower Petal Indicators
Otto Phanstiel

3.021 Cabbage Patch Chemistry
Carol B. Collins

3.022 Plant Indicators for Acids and Bases
Carole R. Goshorn

3.023 What Makes a Good Conductor
Mary V. McCrary

3.024 Removing Silver Tarnish
Diane Moore Jernigan

3.025 The Story of Calcium
Margaret Christoph

3.026 The Chemical Properties of Marble
Terry Thompson

3.027 Electrographic Metal Detectors
Sr. Mary Ethel Parrott

3.028 The Test Tube Mystery
Valeria Alston

3.029 Electrical Charges in Colloidal Solutions
Valeria Alston

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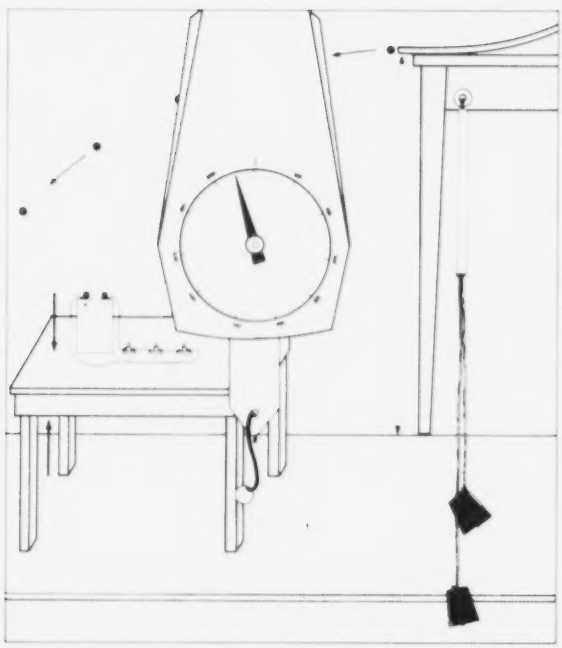
IV. PHYSICS

4.001 Uniform Motion
Charles Lang
4.002 An Inuit Yoyo
Sandra J. Walton
4.003 Where Is Your Center of Gravity?
Thomas R. Bross
4.004 Water Rockets
Daniela Taylor
4.005 Projectiles and Gravity
David C. Tucker
4.006 Fighting Friction
Jeanne Lundquist
4.007 Pitching Speed
Arthur Eisenkraft
4.008 Behavior of the Simple Pendulum
Carl C. Duzen
4.009 Clocking Speedy Sound Waves
Linda J. Kanipe
4.010 Garden Hose Bugle
Donald A. Schaefer
4.011 Roy G. Biv
Charles W. McLaughlin
4.012 Images Formed by Plane Mirrors
Donald A. Schaefer
4.013 Refraction and Total Internal Reflection
Alfred W. Guenther
4.014 The Mysterious Blinking Neon Light
Michael G. Pearson
4.015 Series Circuits
Charles Lang
4.016 Parallel Circuits
Charles Lang
4.017 Making a Light Bulb
Connie Tiliakos



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INTRODUCTION

Science Experiments On File™ has two principal purposes:

1. To provide a resource for students, grades 6–12, of every level of science ability and expertise, from which they can obtain challenging, inexpensive, *fun* science experiments to do independently at home or in the school lab.
2. To offer a forum through which a group of master teachers—selected by the National Science Foundation to receive Presidential Awards for Excellence in Science Teaching—can share a concrete product of their experience with other science teachers across the country.

When we began doing editorial research for Science Experiments On File™, we discovered the need for a source of practical science experiments that would cover a wide range of subjects at different grade levels and include projects for both general and advanced students. This book, addressed to students for their independent use as well as to teachers as a supplement to the standard texts they teach, is meant to answer that need. Since the contributors are practicing teachers in today's school system, the experiments function meaningfully in the context of current science curricula. The instructions are comprehensive and expressed in terms appropriate to the grade level of the specific experiments, so that students can work with maximum independence — in many cases entirely on their own and in others with an adult present mainly to supervise procedures for safety. All of the materials called for have been checked against state school board lists. See the Special Safety Note and the General Safety Precautions that follow this introduction.

As in other volumes in the On File series, the entries in this book are self-contained and copyright free. A student or teacher can find the experiment she or he wishes to use, copy it along with the General Safety Precautions at the beginning of the book, and be ready to proceed with the project with no other reference materials necessary.

All the experiments appear in a standard, concise format of topic, introduction, time and materials needed, safety precautions, procedure and analysis. Wherever necessary, data tables have been included to help students record and organize experimental results for analysis. Figures have been used throughout to further clarify procedures. We have kept explanatory prose to an absolute minimum in an attempt to focus attention on the experimental procedure itself and what can be learned from observation and analysis of the immediate physical results. Our "findings" for all of the experiments are in a separate section at the end of the book. Thus, a student working alone can compare her or his own responses to the questions posed in the "analysis" section with the findings reported in the book.

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Started in 1983, the Presidential Award program is intended to identify outstanding teachers who can serve as models for their colleagues. With the publication of this book, we hope to further that goal by offering a practical format in which these master teachers can share their experience with other teachers, besides giving students across the country direct access to the experiments they have found to be most successful.

We asked the teachers to contribute their favorite experiments — the ones that they have found to be most effective in illuminating important scientific concepts, and that were most challenging and exciting for students. From the more than 200 experiments we received we have selected the ones in this volume. They range from fairly elementary projects that can be done in a class period with little preparation to projects that take several weeks and involve a good deal of precise laboratory techniques and creative problem solving. Some are variations on classic experiments that over the years have taught generations of science students the principles of the physical universe. Others are standards with a twist, and there are some that are so unusual and innovative that we're fairly sure you'll never have encountered anything like them. For all their diversity, they have one important characteristic in common: they all work well in an independent setting.

All of the experiments were reviewed by a panel of practicing teachers who helped make the final selections and suggested editorial changes. Then each of the experiments was tested by students and other lay people. Based on these tests, the directions and explanations have been carefully revised by the authors to ensure that they are detailed and clear enough for non-experts to successfully perform the experiments and achieve rewarding and illuminating results. That doesn't mean that all the experiments are easy or that they encourage superficial analysis. In fact, when we contacted scientists to help us analyze our results and edit the experiments accordingly, we found that even some of the most basic experiments brought some very subtle ideas into focus, as well as raising a few questions still under debate in the scientific community. The editorial challenge has been to describe these projects clearly and simply, while respecting the complex issues they raise.

Our primary goal has been to leave initiative to the students. This is the reason for the brevity with which we have explained each experiment's central terms and concepts; we view these experiments as schematic "maps" intended to guide students into an experimental world whose terrain they can discover for themselves. Of course, we also hope that the brief journeys traced in this book will inspire some students to venture farther into that world, so that they themselves may someday become the mappers of still uncharted territories.

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SPECIAL SAFETY NOTE TO EXPERIMENTORS

Each experiment includes a short list of special safety precautions that are relevant to that particular project. However, these do not include all of the basic safety precautions that are necessary whenever you are working on a scientific experiment. For this reason, it is absolutely necessary that you read, copy and remain mindful of the General Safety Precautions that follow this note.

Experimental science can be dangerous, and good laboratory procedure always includes carefully following basic safety rules. Things can happen very quickly while you are performing an experiment. Things can spill, break, even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following basic safety guidelines the *entire* time you are performing the experiment, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual experiments. We made this choice for one reason: We want you to take very seriously every safety precauation that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical to your safety.

One further note—The book assumes that you will read the safety precautions that follow, as well as those at the head of each experiment you are preparing to perform, and that you will *remember* them. Except in rare instances, these precautions will not be repeated in the procedure itself. It is up to you to use your good judgment and pay attention when performing potentially dangerous parts of the procedure. Just because the book does not say BE CAREFUL WITH HOT LIQUIDS or DON'T CUT YOURSELF WITH THE KNIFE does not mean that you should be careless when simmering water or stripping an electrical wire. It does mean that when you see a special note to be careful, it is extremely important that you pay attention to it.

If you ever have a question about whether a procedure or material is dangerous, wait until you find out for sure that it is safe.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge or taking unnecessary risks can be avoided by practicing safety procedures and being alert while conducting experiments. Be sure to check the experiments in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone.

PREPARE:

—Clear all surfaces before beginning experiments
—Read the instructions before you start
—Know the hazards of the experiments and anticipate dangers

PROTECT YOURSELF:

—Follow the directions step-by-step; do only one experiment at a time
—Locate exits, fire blanket and extinguisher, master gas and electricity shut offs, eye wash and first aid kit
—Make sure there is adequate ventilation
—Do not horseplay
—Wear an apron and goggles
—Do not wear contact lenses, open shoes, loose clothing or loose hair
—Keep floor and work space neat, clean and dry
—Clean up spills immediately
—Never eat, drink or smoke in laboratory or near work space
—Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult

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USE EQUIPMENT WITH CARE:
- —Set up apparatus far from the edge of the desk
- —Use knives and other sharp or pointed instruments with caution
- —Pull plugs, not cords, when inserting and removing electrical plugs
- —Don't use your mouth to pipette; use a suction bulb
- —Clean glassware before and after use
- —Check glassware for scratches, cracks, and sharp edges
- —Clean up broken glassware immediately
- —Do not use reflected sunlight to illuminate your microscope
- —Do not touch metal conductors
- —Use only low voltage and current materials such as lantern batteries
- —Be careful when using stepstools, chairs and ladders

USING CHEMICALS:
- —Never taste or inhale
- —Label all bottles and apparatus containing chemicals
- —Read labels carefully
- —Avoid chemical contact with skin and eyes (wear goggles, aprons and gloves)
- —Do not touch chemical solutions
- —Wash hands before and after using solutions
- —Wipe up spills thoroughly

HEATING SUBSTANCES:
- —Use goggles, apron and gloves when boiling water
- —Keep your face away from test tubes and beakers
- —Never leave apparatus unattended
- —Use safety tongs and heat-resistent mittens
- —Turn off hot plates, bunsen burners and gas when you are done
- —Keep flammable substances away from heat
- —Have fire extinguisher on hand

WORKING WITH MICRO-ORGANISMS:
- —Assume all micro-organisms are infectious—handle them with care
- —Sterilize all equipment being used to handle micro-organisms

GOING ON FIELD TRIPS:
- —Do not go on a field trip by yourself
- —Tell a responsible adult where you are going and maintain that route
- —Know the area and its potential hazards, such as poison plants, deep water and rapids
- —Dress for terrain and weather conditions (prepare for exposure to sun as well as to cold)
- —Bring along a first-aid kit
- —Do not drink water or eat plants found in the wild
- —Make use of a buddy system; do not do outdoor experiments alone

FINISHING UP:
- —Thoroughly clean your work area and glassware
- —Be careful not to return chemicals or contaminated reagents to the wrong containers
- —Don't dispose of materials in sink unless instructed to do so
- —Wash your hands
- —Clean up all residue and containerize for proper disposal.
- —Dispose of all chemicals according to all local, state and federal laws.

BE SAFETY CONSCIOUS AT ALL TIMES.

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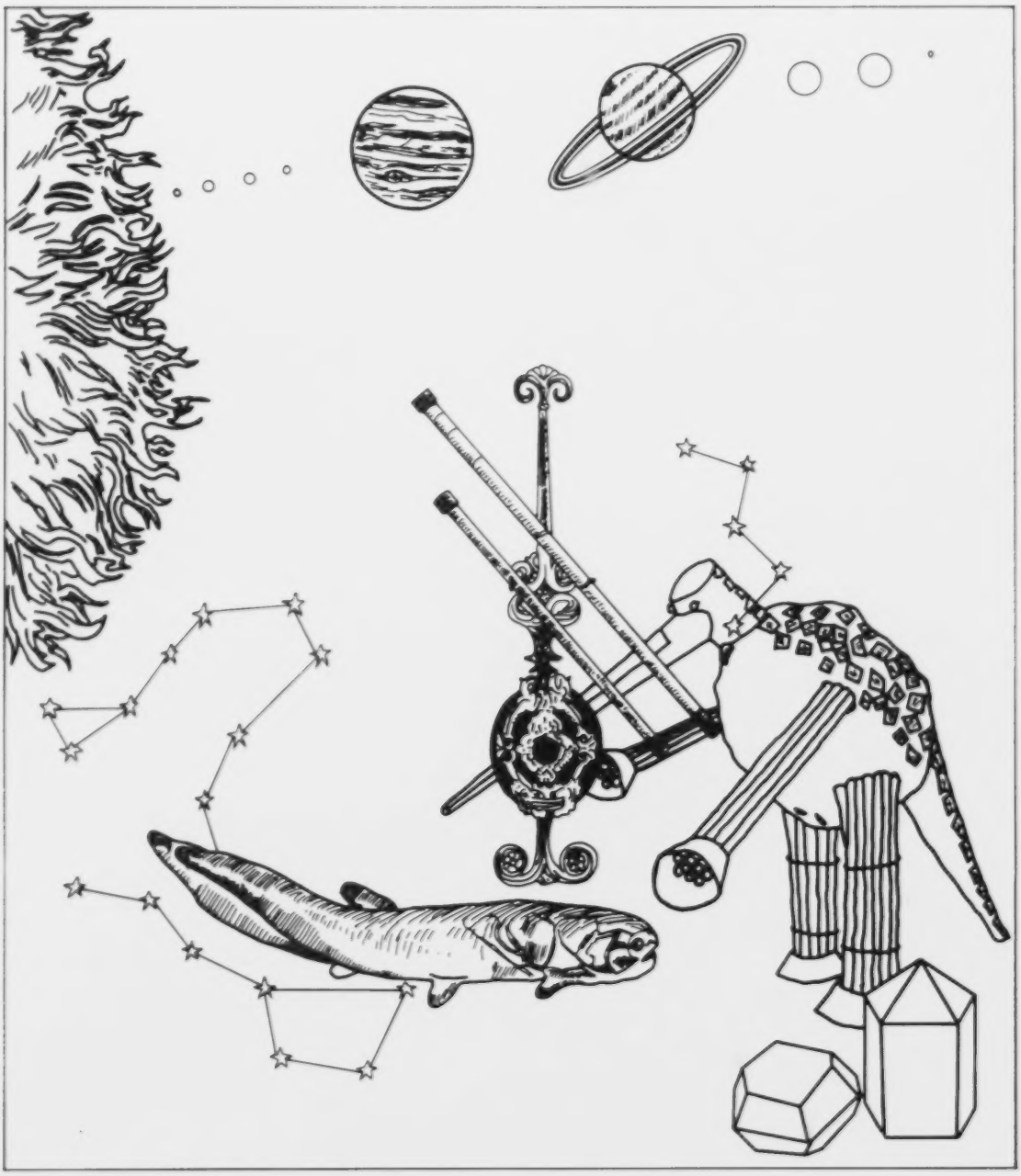
I.
EARTH SCIENCE



DOES YOUR TOWN HAVE ACID RAIN?

James Attison McClanahan

TOPIC:

Measuring the Acidity of Precipitation

INTRODUCTION:

In many parts of the United States and in Canada, water supplies and forests have been affected by acid rain—rain that contains chemical pollutants generated by heavy industry. In this experiment you will test the rainfall in your area to see if it has this problem.

TIME NEEDED:

30 minutes-1 hour to test each sample collected (collection time will vary).

MATERIALS:

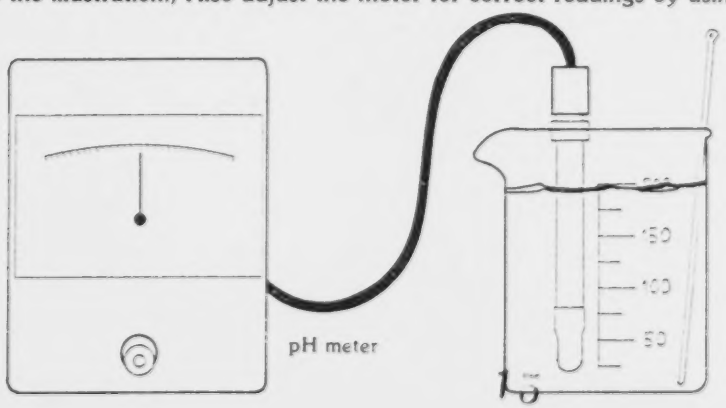
pH meter
pH buffers for pH4, pH7, and pH10
collection container (glass, ceramic, or plastic)
Celsius thermometer
25-ml beaker

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. pH buffers are toxic. Keep them away from mouth, skin, and clothes.

PROCEDURE:

1. Place a glass, ceramic, or plastic container outside the next time it rains or snows. Be sure the container is not next to a building (runoff water from the roof will not give you an accurate measurement of acid rain). Also, place the container on high ground so that you do not collect runoff contaminated by soil.
2. Bring the sample to a temperature of 20° C. Adjust the pH meter for this temperature. (See the illustration.) Also adjust the meter for correct readings by using buffers for pH4, pH7,



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and pH10. Consult your teacher or a science text to find out how to do this.

3. Leave the pH meter probe in the sample for at least 15 minutes before taking a reading. Record your reading and the date it was taken.
4. Continue collecting and testing samples for a month. Average the findings of your tests.

ANALYSIS:

1. What pH readings did you find? Did the readings change over the month you took them?
2. Any area with pH readings from 3.6 to 4.8 has serious problems with acid rain. Readings from 4.8 to 5.6 indicate moderate problems. Readings of 5.6 to 6.9 indicate little danger. Based on your findings, evaluate the seriousness of the acid rain problem in your area.

OUR FINDINGS:

See Section V.

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HOW VULNERABLE ARE LOCAL WATERS TO CHEMICAL POLLUTION?

James Attison McClanahan

TOPIC:

Buffering Capacity of Natural Waters

INTRODUCTION:

Chemical pollution, either as a result of direct dumping or acid rain, threatens many of our streams, rivers, and lakes. These bodies of water have a natural capacity to absorb certain amounts of pollution without affecting their ecosystem. This is called their buffering capacity. The buffering capacity of a solution is the degree to which it can absorb acidic or alkaline substances and maintain a nearly constant pH value. If the amount of pollution exceeds the water's natural buffering capacity, there is a potential danger to its ecosystem. In this experiment you will discover the buffering capacity of your local waters and see how effectively they reduce damage to aquatic life by acid rain and chemical pollution.

TIME NEEDED:

1½ hours

MATERIALS:

glass jars for collecting samples (250 ml capacity)
distilled water
pH meter
medicine dropper
pH buffers for pH4, pH10, and pH7
0.2 M HCl solution
250-ml beaker
Celsius thermometer
stirring rod

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. HCl solution and pH buffers should be kept from touching the skin, mouth, or clothes. Samples of natural water aren't for drinking or contact with eyes. They are likely to contain dangerous bacteria.

PROCEDURE:

1. In glass jars, collect water samples from nearby lakes, rivers, and streams. You will need 200-ml samples. If solids are present in the samples, remove them by filtering or by allowing the sediments to settle to the bottom before you take pH readings.
2. As a control, first find the buffering capacity of distilled water. To do this take a 200-ml sample of distilled water and, using the pH meter, measure its pH at 20°C. (See the illustration.) Using the medicine dropper, add the HCl solution one drop at a time until the pH is lowered to 4. Stir the solution well after each addition of HCl. Wait at least 30 seconds before reading the

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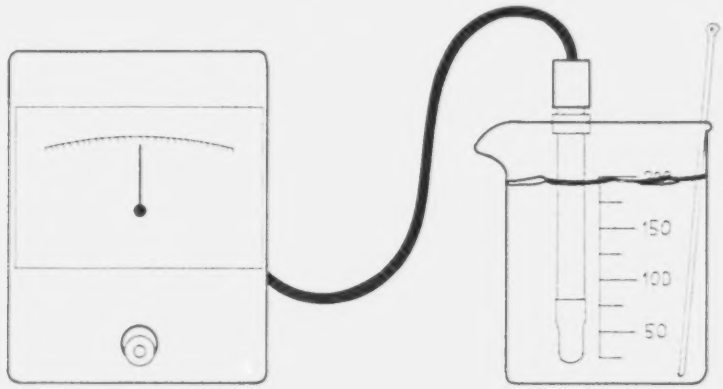
pH meter. Carefully count the number of drops required to reach the desired pH. Record this figure. You will use this base number of drops as a comparison.



pH meter sample

3. Repeat the procedure in step 2 for each of your samples of natural water. To find the buffering capacity of each sample, subtract the base number you found in step 2 from the number of drops required for the sample.

ANALYSIS:

1. A body of water with a buffering capacity of 40 or higher is relatively safe from acid rain. A body of water with a buffering capacity of 4 or 5 may be in immediate danger if the precipitation is very acidic. Based on your data, how vulnerable are the bodies of water in your area to acid rain?
2. If you performed the experiment DOES YOUR TOWN HAVE ACID RAIN?, relate the results of that experiment to the results of this one. How would you rate the overall dangers of acid rain to your town? What impact might these dangers have on life in your town?

OUR FINDINGS:

See Section V.

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WATER CURRENTS

Ross L. Iversen

TOPIC:

Density and Molecular Motion

INTRODUCTION:

The movement of currents in oceans, lakes, and rivers is influenced by changes in water density. In this experiment you will examine how temperature and salinity affect water density.

HYPOTHESIS:

Changes in temperature and salinity cause water to move.

TIME NEEDED:

preparation, 5 minutes plus time to freeze ice cubes
to completion, 30 minutes

MATERIALS:

food coloring
ice cube tray (See PROCEDURE—colored ice cube must be made in advance.)
fish bowl, small aquarium tank, or any glass bowl of similar size
small bottle of ink
salt
test tube or cup
hot tap water (43° C or 110° F.)
Celsius or fahrenheit thermometer

Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

Part A

1. Several hours before you need to begin the experiment, add at least 5 drops of food coloring to a small amount of water. Pour the colored water into an ice cube tray to make 1 colored ice cube. Make sure the color is very dark.
2. Fill a fish bowl, aquarium tank, or other glass container to the rim with room temperature water. Let it stand for about a minute so that the water will have a chance to settle before you start.
3. Place the colored ice cube *very gently* along the edge of the tank and observe for 1 minute or more. Record your observations. Do not disturb the tank until after the ice cube has completely melted. Observe again and record your observations.

Part B

1. Empty the fish bowl or aquarium and then refill it with fresh water at room temperature.
2. Run hot water until the temperature is at least 110° F (43° C). Fill a test tube or cup half full with this water. Add 5 to 7 drops of ink. *Very gently* pour this colored hot water into the tank. Observe for a minute or more. Record your observations.

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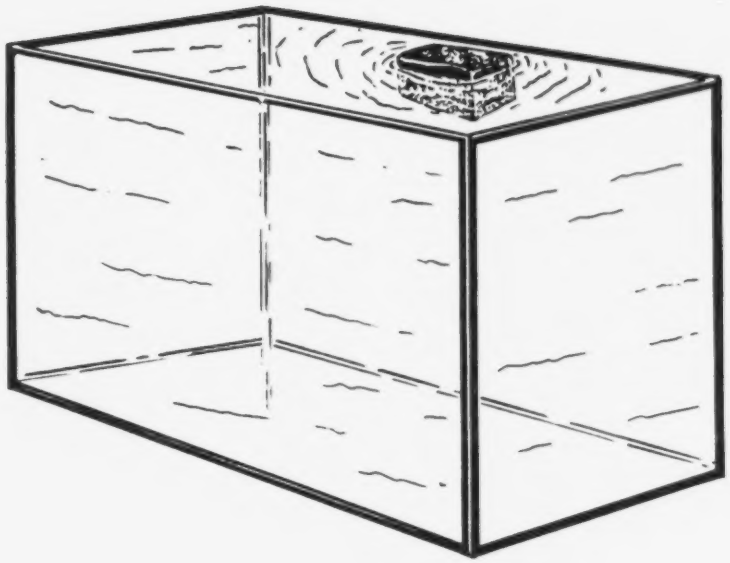

Part C

1. Empty the container and then refill it with fresh water at room temperature.
2. Fill the test tube or cup half full of colored salt water. (Use 5-7 drops of ink to give it a dark color and ½ teaspoon of salt.) *Very gently* pour the colored salt water into the tank and observe. Record your observations.

ANALYSIS:

1. What happened to the cold colored water in *Part A*? Try to explain why this happened.
2. Think of a situation in nature that resembles the conditions in *Part A*.
3. What happened when you poured hot water into the tank in *Part B*? Try to explain why this happened.
4. What happened to the colored salt water in *Part C*? Try to explain why this happened.
5. Where in nature might you find conditions similar to those in *Part C*?
6. Is muddy water heavier or lighter than fresh water of the same temperature? Describe an experiment you could do to prove your answer. Carry out your experiment if you wish.

OUR FINDINGS:

See Section V.

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SURFACE AREA AND EROSION

Marie Z. Sullivan

TOPIC:

Erosion

INTRODUCTION:

Erosion is the process by which the earth's surface—rock, sand, and soil—is broken down and transported. Wind, glaciers, ocean waves, and running streams are all agents of erosion. The rate of erosion depends on many different factors. In this project, you will examine the relationship of surface area to the rate of erosion caused by water.

TIME NEEDED:

15 minutes preparation
50 minutes to completion

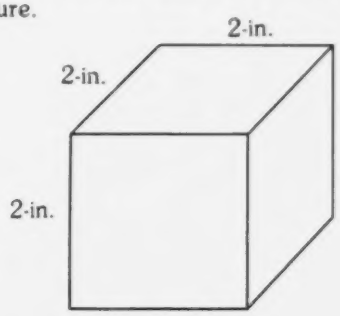
MATERIALS:

2 2-in. cubes of foam rubber or floral foam (one for observation)
ruler
knife or scissors
2 sugar cubes
2 drinking glasses
water
spoon
stopwatch or watch with second hand
measuring cup

PROCEDURE:

Part A.

1. Compute the surface area of one side of the 2-in. cube. Then compute the cube's total surface area and record this figure.



2. Estimate how many 1-in. cubes can be cut from the 2-in. cube.
3. Cut the 2-in. cube into 1-in. cubes. Was your guess correct? How many 1-in. cubes do you now have?
4. Predict the total surface area of all the 1-in. cubes that came from the original cube.
5. Compute the total surface area and record this figure.

Part B.

1. Place 1 sugar cube in a glass.
2. Place ½ cup water in a measuring cup.
3. Pour water into the glass with the sugar, starting the stopwatch or noting the time on your watch.

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4. Stir the sugar and water and observe what happens.
5. When the sugar has dissolved completely, note the time and record how long it took to dissolve.
6. Using a spoon, crush the other sugar cube into a fine powder in another glass. Repeat steps 2-5.

ANALYSIS:

1. Compare the combined surface area of the smaller foam cubes to the surface area of the larger cube from which they were cut. How many times greater is one area than the other? If you have two equal volumes of a substance—one made up of cubes whose sides are half the size of the sides of the cubes in the other, which volume has the greater surface area? How much greater?
2. Was there a difference in the time it took for the whole and crushed sugar cubes to dissolve? If so, which dissolved faster?
3. How did crushing the sugar cube affect its surface area?
4. Based on your results, how does increased surface area affect the rate at which a substance dissolves in water?
5. Explain how your results might relate to the erosion process. If the foam were rocks washed by the tide, which would erode faster, the larger cube or the 8 smaller cubes?

OUR FINDINGS:

See Section V.

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SETTLING RATE AND LAYERING OF VARIOUS SIZED PARTICLES

Alan Schwartz and Dan Griesbach

TOPIC:

Particle Size and Settling Rate

INTRODUCTION:

Most of the rocks on the earth's surface are sedimentary. They were formed when solid material settled out of ice, air, or water and accumulated either on dry land or under water. Sedimentary particles are deposited in layers depending on their mass. In this experiment, you will observe the effects of particular mass on settling rate, illustrating how a stream might form various layers, or strata.

HYPOTHESIS:

Objects with greater mass will settle faster than those of lesser mass.

TIME NEEDED:

45 minutes

MATERIALS:

clear plastic tube with inside diameter of approx. 2.5 cm (A 5-6-ft. tube gives best results, but 3-ft. tube will work.)
test-tube clamp and ring stand
rubber stopper or cork to fit plastic tube
20 solid plastic beads of *each* of the following sizes: 3 mm, 6 mm, 9 mm (Don't use polypropylene beads or other floating types. Exact size of beads is not as important as relative sizes.)
water
watering can or pitcher
funnel to fit inside plastic tube
index card
jar with mouth approximately the size of the tube mouth
stopwatch
bucket
step stool (if using 6-ft. tube)

Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

Preparation:

1. Hold the clear plastic tube vertically with the test-tube clamp and ring stand or similar mechanism (pliers or C-clamp held in a vise, etc.). (See figure 1.) The bottom of the tube should be close to the floor.

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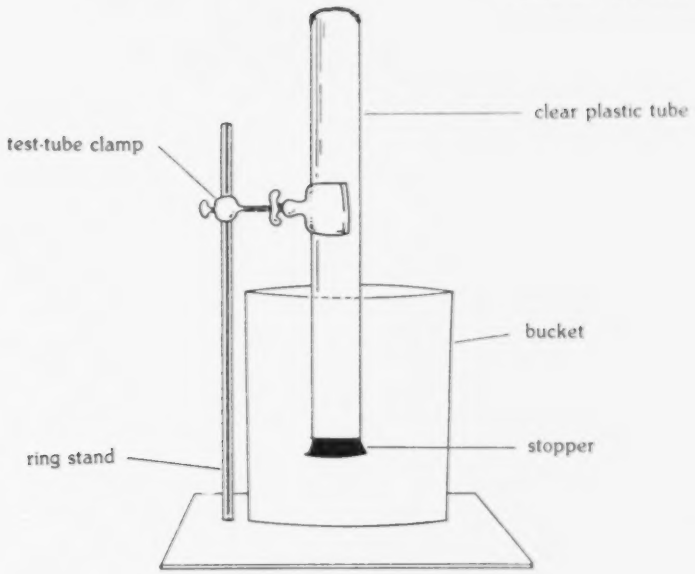

figure 1

2. Stopper or plug the bottom of the tube.
3. Place a bucket under the tube so that water leaking or spilled will not reach the floor, where it would create slippery conditions.
4. Carefully using a funnel, fill the tube with water from a plastic pitcher or watering can. If you are using a long tube, use a step stool to reach the top.

Part A

1. Select one of the smallest beads. Hold it just over the top of the tube. Drop it, timing (with the stopwatch) how long it takes to hit the bottom.
2. Record the time on the Data Table.

DATA TABLE

Bead Size	Time Needed to Sink				
	Trial 1 (1st Bead)	Trial 2 (2nd Bead)	Trial 3 (3rd Bead)	Total (3 Trials)	Average (3 Trials)
Small					
Medium					
Large					

3. Repeat steps 1 and 2 twice with 2 more of the smallest beads.
4. Next, separately time and record the descent of 3 medium-sized beads.
5. Repeat with 3 larger beads.
6. Average the time for each size, and complete the Data Table.

Part B

1. Remove all beads from the tube by *slowly* easing the stopper out of the tube. Pull the stopper out gradually, allowing the water to drain gradually into the bucket. Since the water is under pressure, it will shoot out forcefully if the stopper is removed quickly.

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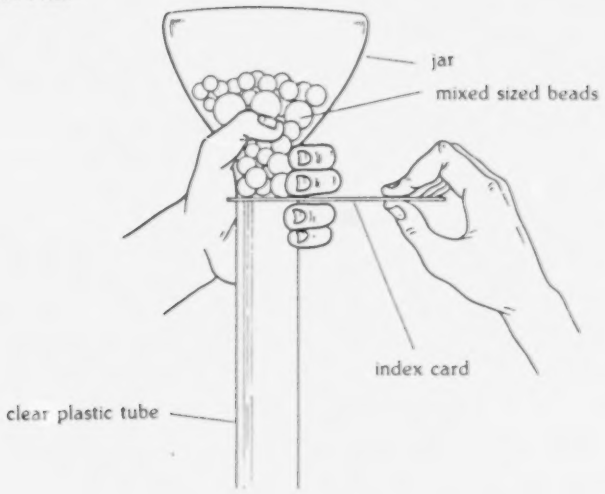

figure 2

2. Replace the stopper and refill the tube with water.
3. Mix approximately 20 small beads, 15 medium beads, and 10 large beads together in a jar with a mouth about the same size as the mouth of the tube.
4. Place an index card over the jar mouth and invert the mouth over the top of the tube. Let it rest there, while you hold the jar against the tube neck with one hand and the index card with the other as shown is figure 2. With a quick movement, pull the card from between the jar and tube to release all the beads into the tube.
5. After they reach the bottom, observe the positions of the small, medium, and large beads. Make an *accurate* drawing.

ANALYSIS:

1. Which beads sank the fastest? Why?
2. Which beads sank the slowest? Why?
3. If the rate of sinking is consistent for all beads of the same size, then when the mixture is dropped, all the fastest ones should form the bottom layer. Did this occur? Can you explain your results?
4. If a bank of a stream falls into the moving water of the stream itself:
   a.) Which size particles will settle to the bottom first?
   b.) Which ones as a result of their slower settling will remain in the moving water longer before dropping to the bottom?
   c.) What pattern will develop in particle size distribution on the bottom as you go downstream?

OUR FINDINGS:

See Section V.

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CAN YOU PREDICT THE MOVEMENT OF AIR?

Marie Z. Sullivan

TOPIC:

Convection Currents in Air

INTRODUCTION:

Convection is a method of heat transfer in gases or liquids that results from large-scale movements of unevenly heated substances because of changes in density. Convection helps explain a number of phenomena in our lives—how weather is formed, why balloons rise, or how our houses are heated. In this experiment you will observe the action of convection.

TIME NEEDED:

30 minutes

HYPOTHESIS:

Hot air rises.

MATERIALS:

2 identical wide-mouth jars (20-oz. size)
6-in. piece of rope or punk stick
index card slightly larger than mouths of jars
masking tape
refrigerator
hot and cold running water

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. Handle burning rope or punk carefully. After removing from jar, place in water for several minutes to make sure fire is completely extinguished.

PROCEDURE:

1. Before you execute the experiment, read through the steps below. Try to predict what will happen after step 4 and then after step 6. Write down your predictions.
2. Refrigerate one jar for 5 to 10 minutes to cool both the jar and the air inside. Place the second jar, bottom up, under hot running water in the sink. This jar and the air in it will be warmed.
3. Remove the jar from the refrigerator and place a smoking piece of rope or a smoldering punk inside the cooled jar for 10 to 20 seconds. The smoke will enable you to view air movement. As soon as the jar begins to fill with smoke, remove the rope or punk and place the index card over the mouth of the jar immediately.
4. Dry the warmed jar and place it upside down over the index card. The opening of the jars should be separated by only the card. With the cooled jar on bottom and the warmed jar on top, pull the card out from between the jars, holding the two jars together.

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5. Observe the visible air (smoke). Record your observation.
6. Tape the mouths of the jars together and flip them so the cooled jar is above the warmed jar. Hold the two jars tightly together when you turn them. Leave them in this position for 3 to 5 minutes.
7. Observe the visible air (smoke) again. Record your observation.

ANALYSIS:

1. What did you observe when you removed the index card from between the jars? Compare the result with your prediction of what would happen. Write an explanation for what you observed.
2. What did you observe after reversing the positions of the jars? How did the result compare with your prediction of what would happen? Write an explanation for what you observed.

OUR FINDINGS:

See Section V.

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DETERMINING THE GEOLOGIC AGE OF ROCK SAMPLES

Gary L. Stringer

TOPIC:

Geologic Range of Fossil Organisms

INTRODUCTION:

Fossils collected from the same rocks can be utilized to determine the geologic age of the rocks. This is accomplished by plotting the geologic range of each fossil and determining where the ranges overlap. The overlap indicates when the organisms could have lived together, and thus, the age of the rocks. In this exercise, you will use the principle of geologic ranges of fossils to date hypothetical rock samples.

TIME NEEDED:

30 minutes

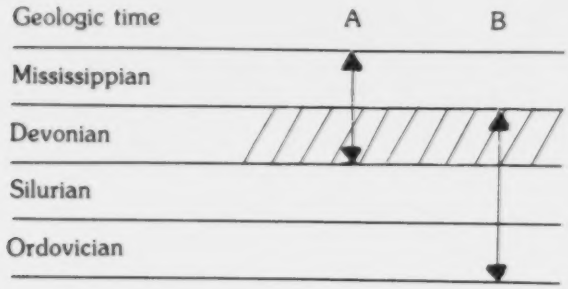
MATERIALS:

reference book on fossils and paleontology

PROCEDURE:

The diagram below indicates how overlap in the geologic range of fossils can be used to date rocks.

A = *Microcyclus* Geologic range = Devonian to Mississippian
B = *Streptelasma* Geologic range = Ordovician to Devonian



The overlap is Devonian. The rock containing these two fossil corals is Devonian in age.

The diagram illustrates the completed procedure for two fossil corals. You will use this procedure to analyze data about various rock samples. Read the description of types of fossils found in each rock sample. Then use copies of the Geologic Time Scale below to date each rock sample.

ANALYSIS:

1. A student collected the following fossils from the Graham Formation in Texas. What is the age of the formation?

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Pentremites (type of echinoderm) = Mississippian to Pennsylvanian
Lophophyllidium (type of horn coral) = Pennsylvanian to Permian
Archimedes (type of bryozoan) = Mississippian to Permian

2. The following trilobites were found together in a shale. Using the geologic range of the different trilobite genera, determine the age of the shale.

Phacops = Silurian to Devonian
Illaenus = Ordovician to Silurian
Dalmanites = Silurian to Devonian

3. A student collected fossils from two formations. He used *Index Fossils of North America* to identify the fossils and determine their geologic ranges. Determine the age of the two formations.

Formation 1

Halysites (coral)
Ordovician to Silurian

Astraeospongium (sponge)
Silurian to Devonian

Eurypterus (arthropod)
Ordovician to Permian

Phacops (trilobite)
Silurian to Devonian

Formation 2

Pentremites (blastoid)
Mississippian to Pennsylvanian

Lophophyllidium (coral)
Pennsylvanian to Permian

Archimedes (bryozoan)
Mississippian to Permian

Neospirifer (brachiopod)
Pennsylvanian to Permian

4. The following fossil assemblage was found in a limestone. Determine the age of the limestone.

Allorisma (pelecypod) = Mississippian to Permian
Bellerophon (gastropod) = Ordovician to Triassic
Aulopora (coral) = Silurian to Pennsylvanian
Loxonema (gastropod) = Ordovician to Mississippian
Sphenophyllum (plant) = Mississippian to Pennsylvanian

5. The plant fossils listed below were found in a formation. Is it possible for dinosaur remains to be found with them? (Hint: Dinosaurs lived from the Triassic to Cretaceous).

Poplar (Cretaceous to Recent)
Willow (Cretaceous to Recent)
Gingko (Jurassic to Recent)
Birch (Cretaceous to Recent)
Fig (Cretaceous to Recent)

6. A movie showed a group of primitive humans fighting a *Tyrannosaurus rex* (a theropod dinosaur). Look up the geologic range of humans in a reference book. What is wrong with the movie script?

OUR FINDINGS:

See Section V.

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THE GEOLOGIC TIME SCALE

Eras	Periods	Epochs	Millions of years before present	Major events
CENOZOIC	Quaternary	Holocene		Development of modern man
		Pleistocene	2	Major worldwide glaciation
	Tertiary	Pliocene		Earliest hominids
		Miocene		
		Oligocene		Diversification of mammals
		Eocene		
		Paleocene	65	
MESOZOIC	Cretaceous			Extinction of dinosaurs, marine reptiles, and aerial reptiles First flowering plants
	Jurassic			Dinosaurs dominant First birds
	Triassic		225	Origin of mammals Origin of dinosaurs
PALEOZOIC	Permian			Extinction of trilobites and many other marine invertebrates
	Pennsylvanian			Development of reptiles
	Mississippian			Amphibians dominant on land
	Devonian			Oldest known land vertebrates
	Silurian			Oldest known life on land
	Ordovician			Oldest known vertebrates (jawless fish)
	Cambrian		600	Trilobites dominant No known life on land
PRE—CAMBRIAN	Proterozoic			Origin of metazoan life First eukaryotic cells
	Archeozoic			
	Azoic		4000	First prokaryotic cells in oceans

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LICORICE STICK HALF-LIFE DATING

Michael G. Pearson

TOPIC:

Half-Life Dating

INTRODUCTION:

Every radioactive element decays (becomes stable) at a unique rate. The *half-life* of an element is the amount of time it takes for half of a given number of atoms of that element to become stable. The age of objects that contain radioactive isotopes with known half-lives can thus be calculated by determining the percentage of radioactive material remaining. In this experiment you will construct a model that demonstrates the principle of half-life dating.

TIME NEEDED:

1 hour

MATERIALS:

2 pieces 8 ½ in. × 11 in. graph paper
1 piece cardboard several inches larger than the graph paper
12 10-in. licorice sticks (4 red and 8 black)
white glue
scissors or knife
ruler

Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

1. Glue one of the two pieces of graph paper to the cardboard. Now draw two identical graphs, following directions below, on the two pieces of graph paper.
2. Draw a vertical scale about 1 in. from the paper's left edge and label it *% Radioactive Material.* (See sample graph.)
3. Draw a horizontal scale and label it *Half-Lives.*
4. Glue one red licorice stick to the vertical axis of the cardboard-backed graph. Write 100% on the vertical scale at the top of this stick. (Red licorice represents radioactive material.) Measure the length of the stick and write 100% at the corresponding point on the vertical scale of the second graph without the licorice.
5. Divide and label the vertical scales of both graphs to show percentage by 10s, with the height of the licorice stick equaling 100% and the horizontal axis at 0%.
6. Divide the horizontal axes of both graphs at 1-in. intervals. Label from zero to seven, with zero being the point at which the vertical axis intersects the horizontal. Then draw vertical lines at each numbered point up to the height marked at 100% on the vertical axis.
7. Take another red licorice stick and cut it in half. Glue one half on the cardboard-backed graph on the vertical line marked "1" on the horizontal (half-life) axis. Glue half of a black stick above the red half to create a composite full-length stick. (The black licorice represents the stable

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material formed as the radioactive material decays.) Mark line "1" of the unbacked graph at the height equal to the red licorice.

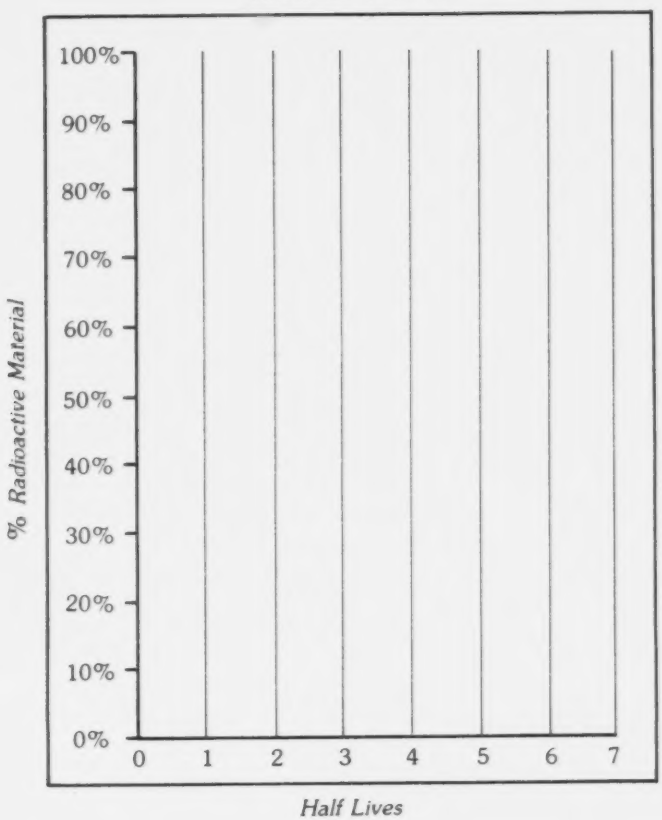
8. Now take the other half of the red stick and cut it in half again. Glue one portion onto the cardboard-backed graph on line "2" to represent the amount of radioactive material remaining after 2 half-lives. Above it, add the length of black licorice needed to completely cover the vertical line and make the stick equal with the others. Again, mark the place on the other graph's line "2" that corresponds to the height of the red licorice on the cardboard-backed graph.

9. Cut the remaining piece of red licorice in half again. Glue and repeat procedure above, including marking the height of the red licorice on the second graph.

10. Continue until you run out of room on your graph or until the small amount of the remaining licorice makes accurate division impossible.

11. On the graph without the licorice, draw a *smoothly curving* line that follows the points marked on the vertical lines. You may eat the remaining licorice, but save one whole red stick for further analysis.

SAMPLE GRAPH



ANALYSIS:

1. Assume each half-life (space between marks on the horizontal axis) represents 5,500 years. Determine the age represented by each red licorice segment. (The half-life of carbon 14, which is commonly used to date plant and animal remains, is about 5,500 years.)

2. Have someone cut the remaining whole piece of red licorice into varying lengths. Assume that the pieces represent amounts of remaining carbon 14. Again, assume that each half-life on the graph is 5,500 years. By finding the correct places for the new pieces of red licorice (carbon 14) on the graph, estimate the age of each new segment.

OUR FINDINGS:

See Section V.

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RECONSTRUCTION OF AN ANCIENT ENVIRONMENT

Gary L. Stringer

TOPIC:

Uniformitarianism and Paleoecology

INTRODUCTION:

Uniformitarianism, sometimes stated as "The present is the key to the past," is the principle that essential laws governing the physical world are unchanged over time. This does not mean that the present environment is the same as it was in the past but that changes have taken place within a consistent framework, according to the same laws still active today. Thus, we can use bits of information that we have about the past (fossils, for example) along with what we know about our present environment to deduce what past conditions were. In this exercise, you will apply the principle of uniformitarianism to determine the nature of a specific site.

TIME NEEDED:

several hours

MATERIALS:

reference books on biology and zoology, especially on shells, fishes, and sharks (The library would be an ideal setting for this project.)

PROCEDURE/ANALYSIS:

A well-known fossil site in northeastern Louisiana has been studied since the early 1800s (see map). Many fossils were first discovered and described at this Eocene site. The fossils are approximately 40 million years old. Numerous phyla of animals are represented by the fossils. Many of the invertebrate and vertebrate fossils from the site are listed below.

Use reference books to find modern counterparts to as many of the fossils as possible. Then utilize the data from the modern animal to make inferences about the fossil animal. For example, one of the fossil corals is *Archohelia*, a hermatypic coral. Modern hermatypic corals live mainly in clear, shallow, marine waters with temperatures from 18° C-29° C. Compile data from the other fossils to determine the probable ancient environment of this site 40 million years ago. How was the environment different from the mixed pine and hardwood forests that are in the area today?

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A LIST OF FOSSILS FROM COPENHAGEN SITE, LOUISIANA

Phylum Porifera
- *Cliona*—marine boring sponge

Phylum Bryozoa
- Cheilostome bryozoas (marine bryozoans)

Phylum Annelida
- *Rotularia*—tubeworm
- *Serpula*—marine worm

Phylum Coelenterata
- *Archohelia*—reef-forming, colonial coral
- *Balanophyllia*—solitary coral
- *Discotrochus*—solitary coral
- *Endopachys*—solitary coral

Phylum Mollusca
- *Atrina*—pen shell clam
- *Callista*—Calico clam
- *Chama*—marine clam
- *Chlamys*—pecten
- *Bathytormus*—sand-burrowing clam
- *Crassostrea*—oyster
- *Gari*—burrowing clam
- *Glycymeris*—zigzag clam
- *Ostrea*—oyster
- *Aragonia*—olive shell
- *Architectonica*—sundial shells
- *Clio*—pteropod; swimming gastropod
- *Conus*—cone shell
- *Cypraea*—cowry shell

Phylum Arthropoda
- *Callianassa*—mud shrimp
- *Arcoscalpellum*—gooseneck barnacle

Phylum Chordata
- *Alopias*—thresher shark
- *Carcharodon*—great white shark
- *Galeocerdo*—tiger shark
- *Ginglymostoma*—nurse shark
- *Isurus*—mako shark
- *Myliobatis*—eagle ray
- *Negaprion*—lemon shark
- *Odontaspis*—sand shark
- *Pristis*—sawfish
- *Albula*—bonefish
- *Ariosoma*—conger eels
- *Arius*—marine catfish
- *Corvina*—drum
- *Diodon*—porcupine fish
- *Myripristis*—soldierfish
- *Sphyraena*—barracuda
- *Crocodylus*—saltwater crocodile
- *Basilosaurus*—toothed whale

OUR FINDINGS:

See Section V.

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MAKE YOUR OWN ALIENS

Michael G. Pearson

TOPIC:

Environmental Adaptation

INTRODUCTION:

The planets in our solar system vary widely. For example, scientists think that the inner planets are earthlike while outer planets might be made up largely of gases. Science has found no signs of life on other planets, but if life were to exist, it would have to adapt to the specific environment of each planet. This activity will help you investigate environmental adaptation by inventing and "creating" a food chain of organisms suited for survival on another planet.

TIME NEEDED:

at least 2 hours

MATERIALS:

assorted root vegetables (potatoes, yams, turnips, parsnips, carrots, rutabagas, etc. Include some distorted shapes.)
clay
white latex paint
colored markers or paints
straight pins
straws, pipe cleaners, foil, wire, construction paper, and other craft or household items
paint brushes

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Do not eat any of the materials used in this experiment.

PROCEDURE:

1. Go to the library and research environmental conditions on other planets in our solar system. Choose one of the planets to be the "home" of a life form you will invent. Find out as many details about the planet as you can. In addition to books your librarian might recommend, you might find the following magazines helpful: *Odyssey, Astronomy, Sky & Telescope, National Geographic.*
2. What kind of creature could survive on your planet? How big would it be? What would it eat? How would it eat and breathe? What would the outer surface of its body be like? What senses would it have? How would they work?
3. Choose a root vegetable for the body of your creature and apply one or two coats of white latex paint.
4. Applying color and common household items, change the basic body into a lifeform showing physical adaptations for survival on the planet. (Consider all requirements of living organisms: *e.g.*, food, reproduction, protection, movement.)
5. At the same time, have someone else create an organism to survive the same environment. (Work apart from each other, so you can obtain independent results.)

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6. Now create additional creatures illustrating the full range of organisms in the food chain on the planet. What does your creature eat? What eats your creature?
7. Make up a genus and species name for each of your creatures.

ANALYSIS:

1. Write a description of the planet's environment and describe how each of your creatures has adapted to survive in it.
2. Compare one of your creatures with one created by someone else for the same planet. Explain which creature seems to be better adapted for the environment.
3. Ask someone to read your description of the planet's environment. Ask that person to make one substantial change in the environment. Then tell what effect that change would have upon each member of the food chain.
4. Describe how one of your creatures might adapt in response to the change in the environment.

OUR FINDINGS:

See Section V.

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MEASURING QUARTZ CRYSTALS

Gary L. Stringer

TOPIC:

Interfacial Angles of Crystals

INTRODUCTION:

The atoms of molecules in crystals are arranged in a regular, repeating pattern that is outwardly manifested by the mineral crystal's plane faces and the angles between them. In this experiment you will measure the plane faces and interfacial angles of quartz crystals to explore their relationship.

TIME NEEDED:

30 minutes

HYPOTHESIS:

Interfacial angles in a crystal remain constant regardless of the size of the crystal's plane faces.

MATERIALS:

at least two quartz crystals (For best results, use crystals that are at least 1½ in. long and significantly different in size.)
masking tape
ruler
contact goniometer (If the science department in your school does not own one, your science teacher may be able to help you make one with a protractor and 6-in. clear ruler. (See figure 3 in the PROCEDURE section.)

PROCEDURE:

1. Choose one of the quartz crystals for measurement. Count the number of sides and record on the Data Table. Stick a small piece of masking tape on each face (side) of the crystal, and number each face (1, 2, 3 . . .). Measure the width of each face to the nearest millimeter. (See figure 1.) Are the faces the same width? Record this information on the Data Table.

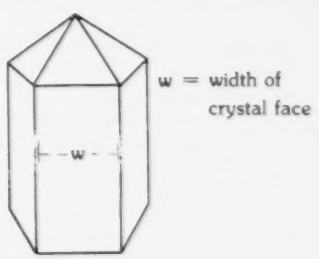

figure 1

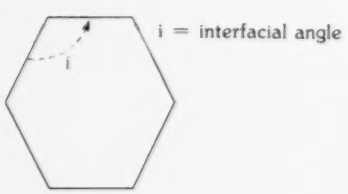

figure 2

2. Use the contact goniometer to measure each interfacial angle of the crystal (the angle between adjacent crystal faces.) (See figure 2.) To do this, place the contact goniometer so that the straight edge of the ruler is against one face and the straight edge of the protractor portion is against the adjacent face. (See figure 3.) Next, read and copy the center of the ruler portion of the contact goniometer. There will be two numbers, one above the other. The outside number is the interfacial angle. Measure each interfacial angle and record on the Data Table.

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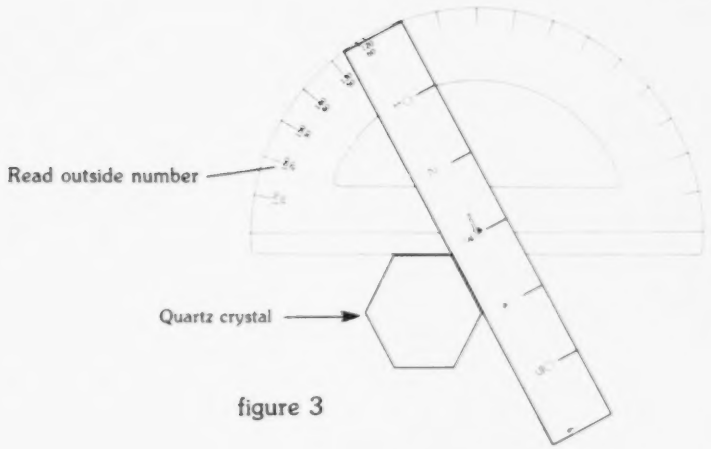

figure 3

DATA TABLE

Crystal 1	Number of Sides:_____		Crystal 2	Number of Sides:_____	
Side Number	Width of Side	Interfacial Angle	Side Number	Width of Side	Interfacial Angle
1.		faces (1 and 2)	1.		faces (1 and 2)
2.		faces (2 and 3)	2.		faces (2 and 3)
3.		faces (3 and 4)	3.		faces (3 and 4)
4.		faces (4 and 5)	4.		faces (4 and 5)
5.		faces (5 and 6)	5.		faces (5 and 6)
6.		faces (6 and 1)	6.		faces (6 and 1)

3. Repeat the procedure with the other quartz crystal.

ANALYSIS:

1. How many faces did Crystal 1 have? Crystal 2?
2. How did the width of the faces of Crystal 1 compare with each other? How did the width of the faces of Crystal 2 compare with each other? How did the width of Crystal 1's faces compare with the width of Crystal 2's faces?
3. How did the interfacial angles of Crystal 1 compare with each other? How did the interfacial angles of Crystal 1 compare with the interfacial angles of Crystal 2?
4. Based on your results, what conclusion can you draw about the relationship between the width of crystal faces and interfacial angles? Based on your data, what tentative conclusion might you draw about interfacial angles?

OUR FINDINGS:

See Section V.

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VIEWS OF THE MOON AS SEEN FROM EARTH

Joyce B. Patton

TOPIC:

Phases of the Moon

INTRODUCTION:

The same side of the moon always faces the earth because the moon makes one revolution around the earth in about the same time it takes for the moon to make one rotation around its own axis. As the moon revolves around the earth, you can see different amounts of its surface (but always the same surface). When the moon is between the sun and the earth, we cannot see the moon's lighted side. This is the new moon phase. Following the new moon, you see a slender crescent, then a quarter moon, then a gibbous (more than a quarter) moon, and finally the full moon. The moon is said to be waxing as it grows. After the full moon, the phases reverse until the moon is invisible again. As we see less light, the moon is said to be waning. This demonstration illustrates the moon's movements.

TIME NEEDED:

1 hour

MATERIALS:

overhead projector (or desk lamp)
2-in. diameter styrofoam ball
pen or marker
toothpick

PROCEDURE:

1. With the pen or marker, section the styrofoam ball into quarters, number them and insert a toothpick at the apex of the quarters. (See figure 1.)

figure 1

2. Now develop your model as follows: your body is the earth; the sectioned styrofoam ball is the moon; the toothpick is the moon's axis; your arm is the force of gravity between the moon and the earth. Note: In the following procedure, turning your body does not represent the earth's rotation, which does not affect this demonstration. Instead, it allows you to view the position of the moon in relation to the earth as the moon revolves.

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3. Darken the room and turn on the overhead projector or desk lamp to represent the sunlight.

4. Stand and face the "sun." (CAUTION: Avoid looking directly into the lamp.) Grasp the toothpick with the thumb and first finger of your left hand. Hold your arm straight out in front of you and raise it so that the "moon" is slightly above your head and directly between you and the "sun." (See figure 2.)

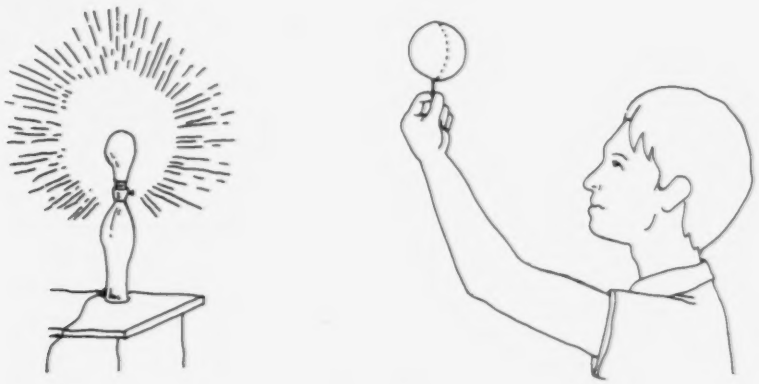

figure 2

Rotate the toothpick so that quarters 1 and 2 of the moon are facing you. Sides 3 and 4 are facing the sun. Shade in what the moon looks like to you from this position on figure 3, position 1.

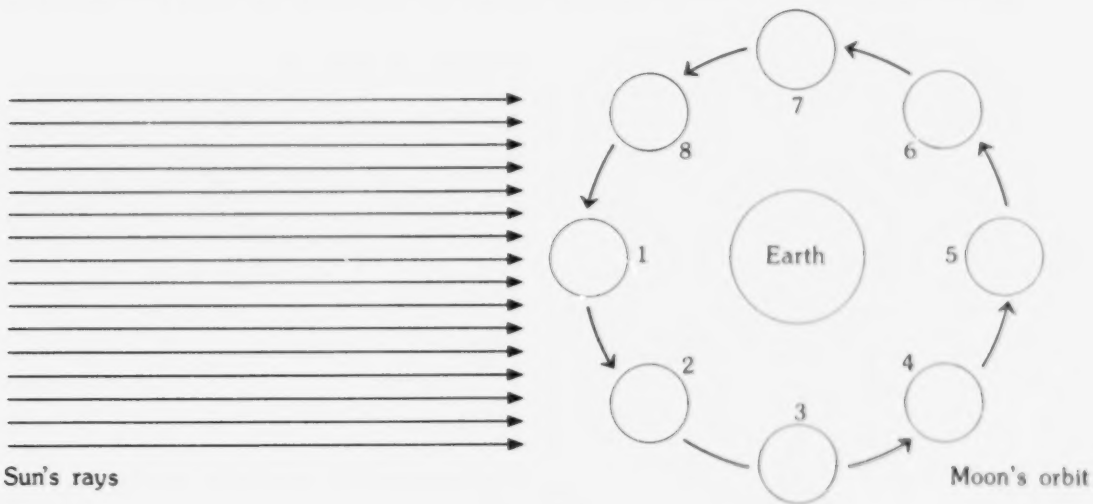

figure 3

5. Keeping the moon above your head, move it about 45° to the left and toward your body by bending your left elbow as seen in figure 4. Shade in position 2. Which side is lighted, the right or the left?

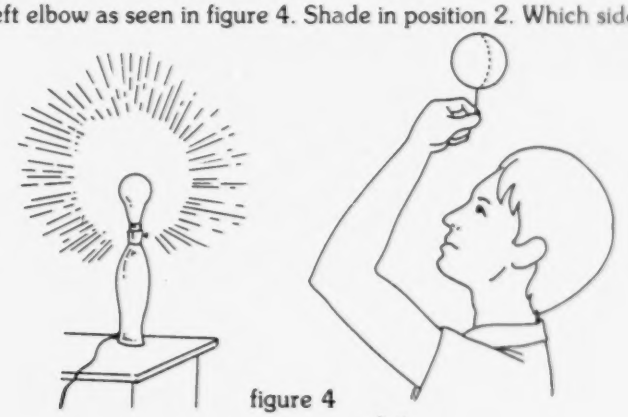

figure 4

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6. With the toothpick, rotate the moon one quarter turn (90°) in a counterclockwise direction.

7. Now turn your body one quarter turn (90°) to your left. Return your left arm to its original position. Shade in the dark area in position 3. Which quarters of the moon—1 and 2 or 3 and 4—are facing you?

8. Continue moving the moon and the earth (your body), repeating steps 5, 6, and 7 until you arrive back to position 1. Sketch the moon as seen in positions 4-8. Be sure to note whether the darkness is on the right or the left. Note which quarters—1 and 2 or 3 and 4—are always visible from the earth.

ANALYSIS:

1. Name and describe the appearance of the eight phases of the moon in the order in which they occur, starting with the new moon.

2. Why is only one side of the moon visible from earth?

3. Sometimes eclipses are produced when the shadow of the moon falls on the earth (solar eclipse) or when the moon moves through the earth's shadow (lunar eclipse). At what moon phase is a lunar eclipse possible? At what moon phase is a solar eclipse possible?

OUR FINDINGS:

See Section V.

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SCALE MODEL OF OUR SOLAR SYSTEM

Sue Anne Nothstine

TOPIC:

Solar System/Measurements to Scale

INTRODUCTION:

Our solar system is vast. The distances between planets and the distances of planets from the sun are hard to imagine. This demonstration will help you understand these relationships.

TIME NEEDED:

2 hours

MATERIALS:

handful of clay
basketball
football field or public park
metric tape measure
metric ruler
13 m adding machine tape
pencil

PROCEDURE:

Part A.

1. Make two copies of the Data Table.
2. Fill in one copy of the Data Table by making the following calculations:
   a) The scale for this model of the solar system is 1 cm = 50,000 km. To find the scale diameter of each planet, divide the mean diameters in column 2 of the Data Table by 50,000. Enter your results in column 3.
   b) To find the scale distance of each planet from the sun, take the actual distances listed in column 4 and divide them by 50,000. Enter your results in column 5. (Note that the figures in column 4 refer to *millions* of kilometers, so that the number 58 stands for 58,000,000.)
   c) To figure out the travel time of light between planets, take the actual distance listed in column 4. Divide this number by 300,000 km/sec., the speed of light. Record the result in column 6.
3. To make your model of the solar system, first form the planets from clay by using the scale diameters in column 3. Use a basketball for the sun.
4. Now take your model planets to a football field or public park. Measure off the scale distances in column 5 to position each planet.
5. If you encounter any problems in completing your scale model, return home and try *Part B.*

Part B.

1. Look at your first Data Table again and fill in your second Data Table. Divide each figure in column 3 and column 5 by 100. This will give you a new scale of 1 cm = 5,000,000 km.
2. Using your new scale, mark the position of the planets and sun and place them on the adding machine tape.

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DATA TABLE

Scale 1 cm =

1 Object	2 mean diameter (km)	3 scale diameter (cm)	4 mean distance from sun (million km)	5 scale distance from sun (cm)	6 travel time of light (sec.)
Sun	1,392,000	27.840			
Mercury	4,900		58		
Venus	12,100		108		
Earth	12,800		150		
Mars	6,800		228		
Jupiter	142,800		778		
Saturn	120,000		1427		
Uranus	51,000		2870		
Neptune	48,600		4500		
Pluto	3,000		5900		

ANALYSIS:

1. How successful was your attempt to make a scale model in *Part A*? Describe any problems you encountered and explain their cause.
2. How successful was your attempt to make a scale model in *Part B*? Describe any problems you encountered and explain their cause.
3. What was the most surprising thing about this experiment?
4. Compare the relative sizes of planets close to the sun with the sizes of those farther from the sun. How do you explain the difference?
5. Which planet doesn't fit the pattern you found in step 4? Explain your answer.

OUR FINDINGS:

See Section V.

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SKYWATCH

Ken Schaefer

TOPIC:

Relative Motion of Stars and Moon

INTRODUCTION:

If you are outside on a starry night, you might notice that the position of the stars, planets, and moon appear to shift slowly. But it is not really the star that moves. The apparent movement is the result of the earth spinning on its axis once every 24 hours. If you observe a star over several days or for a few weeks, you will note that the star seems to have shifted direction. This gradual shift occurs because of the earth's yearly revolution around the sun. In this demonstration you will determine the relative daily and yearly motions of the stars and moon as observed from the earth.

TIME NEEDED:

A few minutes of observation per day, over several weeks

MATERIALS:

sketch pad pencils

PROCEDURE:

Part A

Locate a constellation (or any star or star grouping) in the southern sky. Note its position and sketch it with respect to some features of the horizon such as buildings, trees, or utility poles. (See the illustration.) Record the time and date on the sketch. Note your exact position. Return at intervals of 1 hour and sketch the constellation's new position on your drawing. Repeat the procedure 3 to 5 times. (You'll probably want to do this on a weekend!) Make certain that you are standing in the same position each time and that all observations are made on the same date. What you observed is referred to as the daily motion of the stars.

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Part B

Locate a constellation (or any star grouping) in the southern sky. Note its position and sketch it with respect to some features of the horizon. Record the time and date on the sketch. Note your exact position. Repeat the procedure at intervals of about one week, sketching the constellation's new position on your drawing. Be careful to make each observation at the *same time of night*. If you are performing the experiment in the spring, remember to pick a time that will remain dark for the duration of the experiment. Collect 3 to 5 observations, making certain that they all are at the same time, that you have recorded the date of each one, and that you are standing in the same position. What you observed is referred to as the yearly motion of stars.

Part C

Observe the moon during one day or night at least 4 times, 1 hour apart. For each observation record the time and sketch the moon's position with respect to some features of the horizon. All observations must be made from the same position.

Part D

Observe the moon once a day for 6 consecutive days at the *same time* each day. Sketch the moon's position with respect to some features of the horizon. Record the time and date of each observation and sketch the position on the same drawing. Make certain that all observations are made from the same position.

ANALYSIS:

Part A

1. In what general direction did the stars move during the evening?
2. If the earth is stationary (geocentric theory), then the motion you observed is the stars' real motion. But if the earth is moving (heliocentric theory) and the stars are stationary, what is the direction of the earth's motion?
3. According to what you know about the earth's revolution and rotation, which have you observed?

Part B

1. When observed at the same time over several nights, in what general direction did the stars move?
2. If the earth is stationary, then the observed motion of the stars is their real motion. But if the earth is moving and the stars are not, what is the direction of the earth's motion?
3. Have you observed the earth's rotation or revolution?

Part C

1. You know that the moon is visible at various times, day or night. Is the direction of its motion constant in the day as well as at night?
2. In what direction does the moon move in the course of several hours, day or night?

Part D

1. In what direction does the moon move when viewed over several days or nights at the same time?

OUR FINDINGS:

See Section V.

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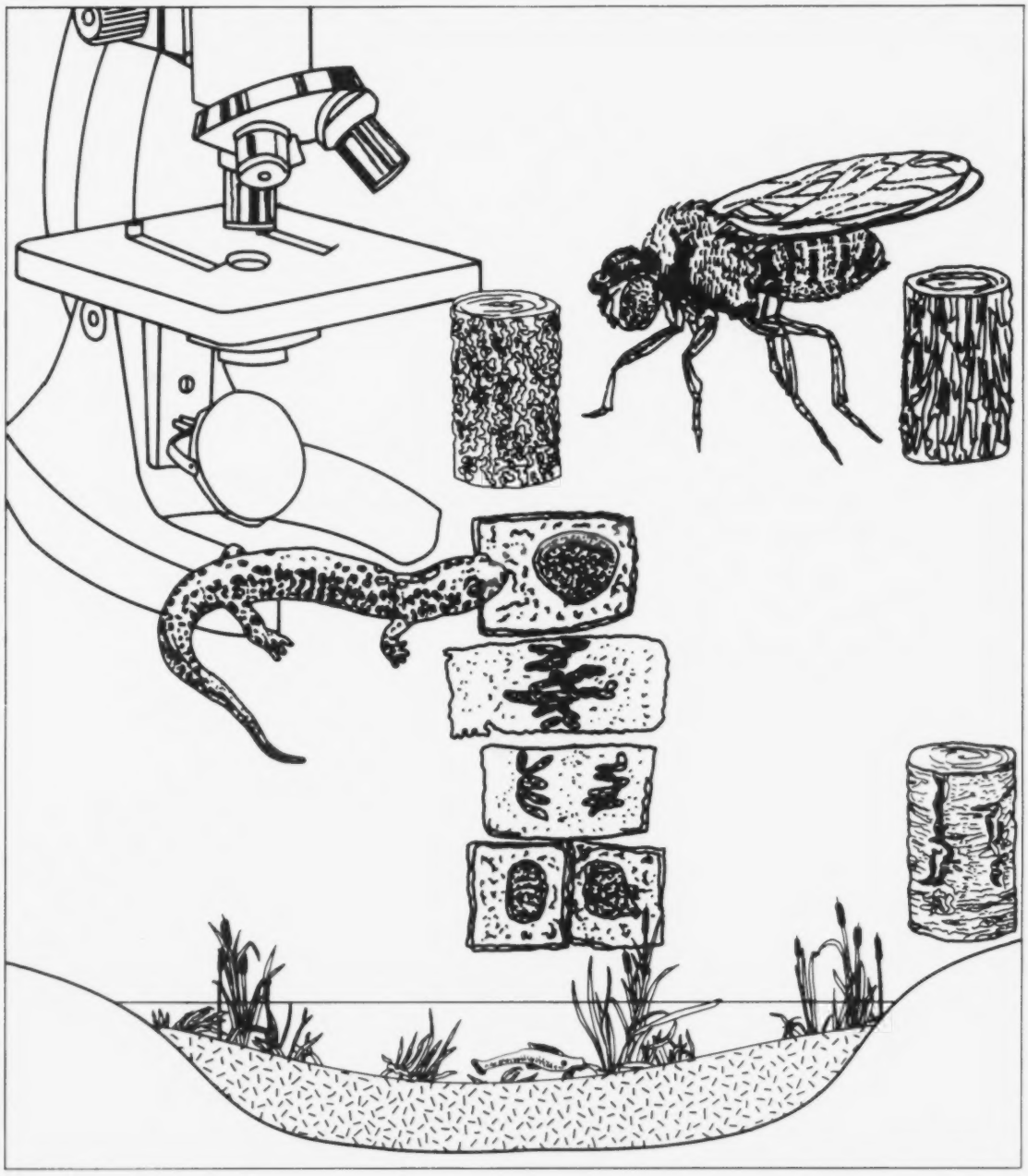
II.
BIOLOGY



SHAPING UP A CLASSIFICATION KEY

Dr. F.H. Shoemaker

TOPIC:

Classification Keys

INTRODUCTION:

Observation is the fundamental tool of scientific research. Classification is a method of observation in which scientists develop a system, based on observed facts, that groups things by similar characteristics. They may begin developing the system by noting obvious features. As observation continues, the system becomes more complex. Classification facilitates in-depth study because it imposes organization on the subjects being studied. In this exercise, you will study the principles of classification by developing your own classification key.

TIME NEEDED:

1 hour

MATERIALS:

paper and pencil
scissors
large sheet paper
glue

PROCEDURE:

1. Make two photocopies of all the geometric figures shown in figure 1 so that you have three copies in all. Then cut out one complete set of figures.
2. On a large sheet of paper, make a chart like the one shown below. The box on the left-hand side should be big enough to contain all the figures you cut out in step 1. Glue them in place in the box.
3. Next, cut up the second copy of the figures and spread them out in front of you. Look over the shapes and edges of the figures. Write down as many characteristics as you can find. For example, *some figures have jagged edges.*
4. Now select two clearly contrasting characteristics, one of which is possessed by at least half the figures and the other of which is possessed by the remaining ones. Divide the figures into Subgroups IA and IB, and place them in the appropriate boxes on the chart, labeling the identifying characteristics that set them apart. Do not glue these figures down until you have completed the next step, in case you want to change your mind and divide them another way.
5. Now look at the figures in Subgroup IA. Can you find two clearly contrasting characteristics, one of which is possessed by at least half of the figures and the other of which is possessed by the remaining half? If so, divide the figures into Subgroups IA1 and IA2. Cut up your third set of figures and paste them in the appropriate boxes. If you can't find a good way to divide the figures, try going back and changing the first division you made into Subgroups IA and IB. Follow the same process to identify Subgroups IB1 and IB2.

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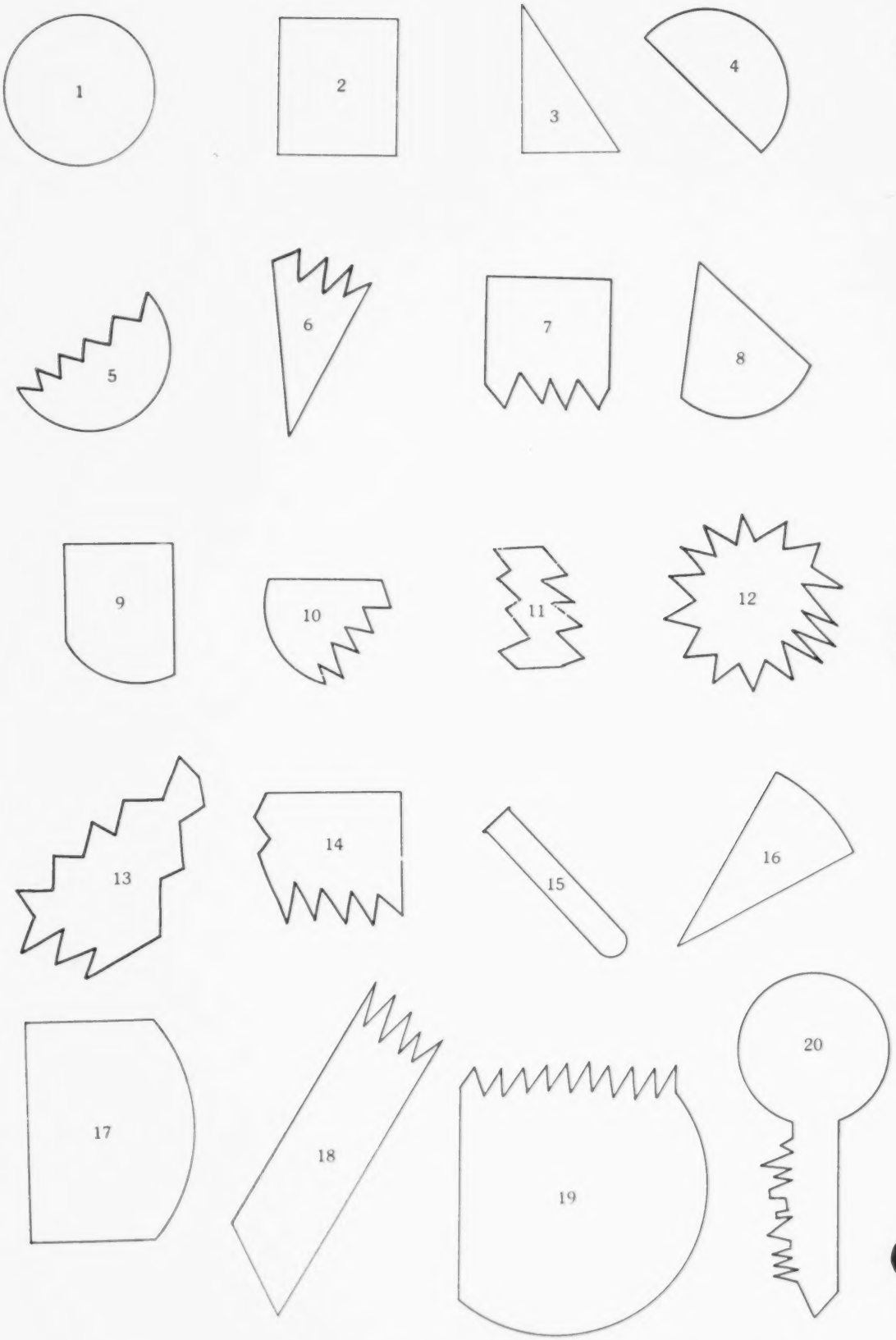
figure 1



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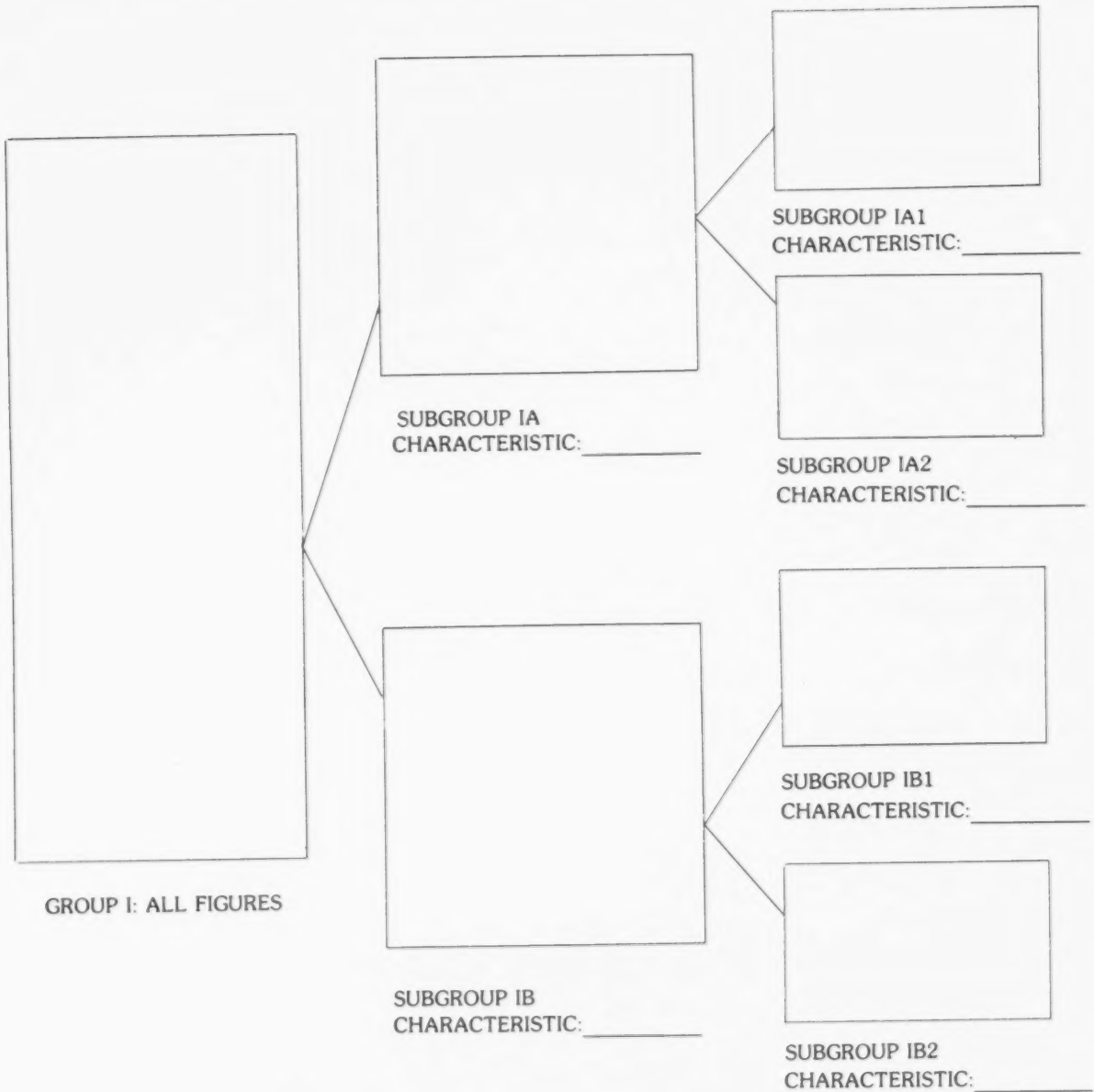
CLASSIFICATION CHART



ANALYSIS:

1. What difficulties did you encounter when you were making up your key?
2. What additional knowledge or information could have made this classification easier?
3. Exchange your key with another student who has made one using the same figures. Write an evaluation comparing the two keys. What are the advantages and disadvantages of each?
4. In what ways is this exercise similar to the work scientists do in classifying plants and animals? In what ways is it different?

OUR FINDINGS:

See Section V.

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COMPARING TREES

Nancy Nowak

TOPIC:

Plant Classification and Ecology

INTRODUCTION:

Because trees are all around us, we often take them for granted. We don't look at them closely or notice the conditions in which they grow. In this exercise, you will examine trees closely so that you can classify them and learn more about their environment.

TIME NEEDED:

several hours or days

MATERIALS:

notebook
metric tape measure (or string and metric ruler)
crayon (preferably large and flat)
large ink pad
field guide to trees
unsharpened, full-sized pencil

PROCEDURE:

1. Choose any two trees to study. Do your experiment in late spring, summer, or early fall when there are plenty of leaves on the trees.
2. First, study the leaves of the trees. Examine a leaf from each tree and compare them. Some trees have needlelike or scaly leaves and some have broad leaves. Are they similar? If you have picked a broad-leafed tree, examine the patterns of the veins in the leaves. *Pinnate* leaves have a single main vein with smaller side veins. *Palmate* leaves have several main veins radiating from one point. (See figure 1.)

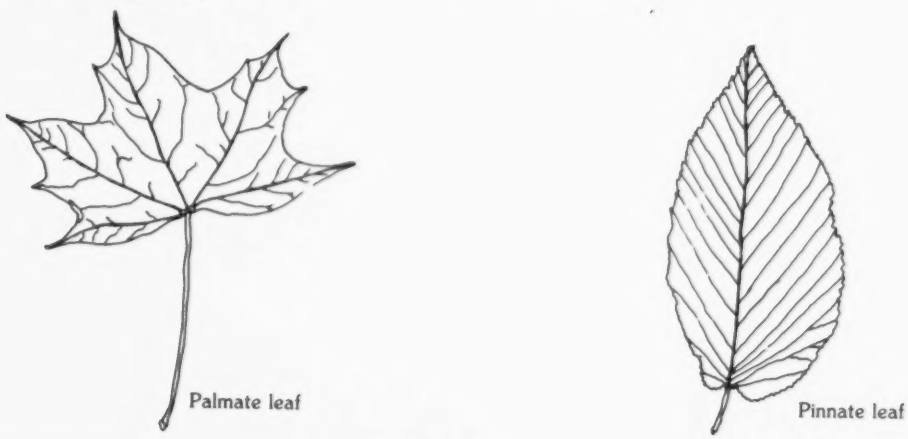

figure 1

Identify the vein pattern of the leaves for each tree. Record your observations on the Data Table.

To illustrate the vein patterns, place each leaf with the vein side down onto an ink pad and rub carefully until the veins are covered with ink. If the pad isn't big enough, you may have to do a section of the leaf at a time. Then place the inked leaf on a notebook page and rub carefully to get a print of the leaf.

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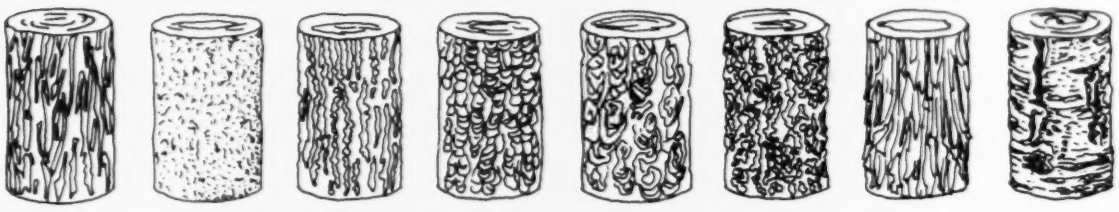
3. Now examine the arrangement of the leaves on each tree. The two main leaf arrangements found in trees are *alternate* and *opposite*, as shown in figure 2. Classify the leaf arrangement patterns for both of the trees you are studying. Record your observations on the Data Table.

Alternate Opposite

figure 2

4. Now study the bark of each tree. Would you describe the bark as smooth, furrowed, scaly, plated, warty, shaggy, fibrous or papery as shown in figure 3? Record your observations. To illustrate the bark, place a sheet of paper on the bark and rub the broad side of a large, flat crayon over it.



Fibrous Smooth Furrowed Scaly Plated Warty Shaggy Papery

figure 3

5. Now estimate the height of each tree. Here is a simple way:
   a) Stand about 10 meters from the tree and hold an unsharpened, full-sized pencil in front of you.
   b) Close or cover one eye and move the pencil back and forth until the bottom of the pencil is at the bottom of the tree and the top of the pencil is at the top of the tree.
   c) Turn the pencil to the side (as if the tree is falling to the side) so one end of the pencil is in line with the bottom of the tree and the pencil is parallel to the ground.
   d) Keep the same eye closed as somebody walks away from the tree until that person seems to be at the end of the pencil. Then tell the person to stop at that point.
   e) Measure the distance from the person to the tree. That is the approximate height of the tree. Record the height on the Data Table.
6. To measure the circumference of the trunk of the tree, use a tape measure with metric measurements or a piece of string. Wrap it around the tree about 1 meter from the ground. If you use a string, measure the length with a ruler afterwards. Record the circumference.
7. Examine each tree for marks, signs of damage caused by the environment, and other individual characteristics. Record these.
8. Each tree is surrounded by living things and nonliving things. The nonliving things are called its abiotic environment. This includes soil, air, light, weather, and human artifacts. Describe the color, texture, moisture level, and compaction of the soil around each tree. Then describe other features of

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DATA TABLE

	Tree 1	Tree 2
Leaf type		
Leaf arrangement		
Type of bark		
Height		
Circumference		
Individual marks and damage		
Abiotic environment	(1) soil: (2) other:	(1) soil: (2) other:
Biotic environment	(1) plants: (2) animals:	(1) plants: (2) animals:

its abiotic environment. Record the description on the Data Table, or use an extra sheet of paper if you need more room.

9. The biotic environment of each tree includes animals and other plants. First describe the plants around each tree, indicating their height, leaf arrangement, and distance from the tree. Then look for signs of animals that live in or near the tree. Describe these signs and tell what animals' presence they suggest. Use an extra sheet of paper if you need more room.

ANALYSIS:

1. Summarize your data about each tree.
2. Trees with the same kind of leaves, leaf arrangement, and bark are usually related. Use your data and a tree identification guide to identify each type of tree you have been studying. Did you choose two related tre s?
3. Describe similarities and differences in the two trees' individual characteristics, such as size, trunk diameter, and damage. Did the trees differ in these characteristics even if they were related?
4. Did the trees share the same biotic and abiotic environments? Describe any significant differences. Did differences in environment seem to have affected the trees in any way?
5. Which of your trees do you think is older? Tell why you think so.
6. Present all your data and illustrations in a report or classroom display.

OUR FINDINGS:

See Section V.

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BUTTERFLY BEHAVIOR

Barbara E. Rothstein, Ph.D.

TOPIC:

Ethology

INTRODUCTION:

Ethology is the study of animal behavior in the wild. To generate reliable information, studies conducted outdoors must be as logically planned, carefully carried out, and meticulously recorded as experiments in a laboratory. Careful observation in a natural setting can yield information about the interrelationships among animal and plant species not obtainable in a laboratory. This project focuses on the behavior patterns of different species of butterflies.

TIME NEEDED:

At least ½ hour per day for a minimum of 1 week

MATERIALS:

clipboard
binoculars
watch with second hand
butterfly and plant identification guides
still camera or video camera (optional)

PROCEDURE:

1. Before you try this activity, find out when butterflies are active in your part of the country. In some areas you will not see butterflies during much of the school year.
2. Decide whether you want to do this activity alone or with one or more partners. The more partners you have, the more sites you can observe.
3. Plan which sites you will observe. Begin by noting in general where you usually observe butterflies. In fields? Trees? Gardens? All of these? Each observer will be responsible for one site.
4. Plan to observe your site for ½ hour after school each day. If possible also observe for ½ hour before school, during lunch and at different times on the weekend. Different butterflies nectar at different times. Continue your observations for at least 1 week.
5. Take the butterfly and plant identification guides with you during your observations.
6. Make copies of the following Data Sheet. Each observer should have 3 to 5 copies for each observation period. Use a separate Data Sheet for each butterfly you observe.
7. First fill in the information at the top of the sheet, including weather conditions and the time you begin. Then choose a butterfly to observe. Describe it as best you can and/or draw it in the space provided. Note the time the butterfly lands on a plant and the time it leaves. Describe, name, and/or draw the plant the butterfly lands on. If the butterfly flies away, look for another butterfly to observe. Use a new Data Sheet for each insect. Try to observe as many different kinds as possible.
8. When your observation period is over, use your butterfly guide to try to identify the species you have observed. Fill in the species names on the Data Sheets and use these names in future observations. Try to identify the plants the butterflies landed on as well.
9. Continue your observations for at least 1 week, preferably longer.

Optional: After your first week of observation, you may choose to record some observations using a still camera or video camera. Use this documentation to back up the information previously recorded on your Data Sheets.

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DATA SHEET

Day_____ Date_____ Observer_____

Location_____ Teacher_____ Period____

Weather:
Temp._____ Clouds_____ Wind (Direction and Speed)_____ Rain_____
Total Observation Time Begins_____ Ends_____

Description of Butterfly: _____
_____

Name of Butterfly:_____

Drawing:

Time Butterfly Touches Plant:_____

Time Butterfly Leaves:_____

Duration of Stay:_____

Description of Plant:_____
_____

Name of Plant:_____

Drawing:

Describe what you saw the butterfly do: _____
_____
_____
_____

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ANALYSIS:

1. What species of butterflies did you observe?
2. Sort your Data Sheets according to species and try to reach some conclusions about each species:
   a) In what type or types of location did you observe the species (park, field, forest, riverbank, etc.)?
   b) At what times did you observe it?
   c) What plants did it prefer?
   d) Make an educated guess about why the butterfly prefers this plant, or explain any information you learned about this question from your guidebook.
   e) Compare how much time the insect generally spends on plants to how much time it spends searching for plants.
   f) Describe the full range of behavior you have observed in this species—feeding, egg laying, etc. Develop a hypothesis for why the butterfly prefers certain plants. For example, it may select for the color or length of the flower tube.
3. File a report on each species you observed—combining your artwork, conclusions, Data Sheets and, possibly, charts and graphs based on your data. You may wish to display any photographs you've taken or screen your videotape for your class.

OUR FINDINGS:

See Section V.

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WHAT DO BIRDS LIKE TO EAT?

Lloyd J. Fugate

TOPIC:

Bird Behavior

INTRODUCTION:

Large and diverse populations of birds live in most areas of the world. In this investigation of the bird life in your neighborhood, you will learn to pick out key field characteristics in order to identify bird species, and you will run an experiment to determine what kind of feed your local birds prefer.

TIME NEEDED:

1 week

MATERIALS:

5 different types of feed; choose from the following:
- oats
- peanuts
- millet
- rice
- soybeans
- whole corn
- cracked corn
- whole sunflower seeds
- sunflower seed hearts

5 blocks of wood or styrofoam plates
5 hand-sized rocks for weight if you are using styrofoam plates
bird identification guide

PROCEDURE:

1. This experiment works best if you have a yard and a ground-floor window from which to observe feeding birds. You should feed birds early in the morning before leaving for school.
2. Measure equal amounts of each type of food and arrange each on a different block of wood or styrofoam plate. Place the feeding stations on the ground in a circle. If you are using plates, put rocks on them to prevent them from blowing away.
3. Sit near a window from which you can observe the birds that come to feed. Observe for 30 minutes and record your observations on copies of the Bird Identification and Feed Preference Chart. Use a different chart for each species of bird. (You can photocopy the chart that follows.) At the end of your observation, use your identification guide to name the bird species. Leave the feed out during the day.
4. After school, collect the feed stations and measure how much feed is left at each station. Rank the feeds from 1 to 5, with 1 the most popular and 5 the least popular. Record the rankings on the Feed Data Table. Take the feeders in for the night.
5. Repeat steps 2-4 every day for a week.

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FEED DATA TABLE

Rankings (1 = most popular, 5 = least popular)							
Name of Feed	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7

ANALYSIS:

1. Summarize the results of your Bird Identification and Feed Preference Charts. How many different species of bird did you observe? Did the same number of birds of a species visit each day? If the numbers varied from day to day, give some possible explanations for why this was so.
2. Add together the total number of all the birds that visited during the week and divide by 7 to get an average of bird visits per observation period.
3. For each species, add together the number of birds that visited the feeding stations during the week and divide by 7 to get an average of daily observed visits. Compare these species totals with the grand total above. Which species were the most frequent visitors? The least frequent?

SUPER BIRD FEED RECIPE

4. Considering all your data, decide what type of feed mixture would be best for a home bird feeder in your yard. Is there one kind of feed that all the birds like? Is there one type of bird that will eat only a certain feed? Are there some birds you would rather not attract? After you have considered all these questions, write your Super Bird Feed Recipe.

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BIRD IDENTIFICATION AND FEED PREFERENCE CHART

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Birds of this species observed*	TOTAL ___	TOTAL ___	TOTAL ___	TOTAL ___	TOTAL ___	TOTAL ___	TOTAL ___
Feeds the birds of this species ate							

*Put a check in the box for each bird of this species you see. At the end of your observation period total the checks and write the number in the space provided.

If the bird ate more than one kind of feed, which did it prefer?_____

1. How big is the bird?

2. Is it slender (like a cuckoo) or stocky (like a starling)?

3. Is the bill cone shaped (like a cardinal), fine (like a warbler), or heavy (like a vireo)? If none of the above, note specialized bill shape.

4. Is the tail a) forked (like a barn swallow), b) notched (like a blackbird), c) square (like a sharp-shinned hawk), d) rounded (like a bluejay), or e) pointed (like a mourning dove)?

5. Does it have an eye ring or an eye line or is the eye plain?

6. Does it have plain wings or wing bars?

7. Is the breast plain, spotted, or streaked?

8. Its most striking colors are: gray, slate, brown, chestnut, black, blue, white, red, yellow, orange, green, olive, other_____ (Underline one or more.)

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WHERE DO PILL BUGS LIKE TO LIVE?

Lloyd Fugate

TOPIC:

Insect Populations

INTRODUCTION:

All organisms prefer to live in the environment to which they are adapted. In this demonstration, you will study a pill bug population to determine the environmental conditions to which these crustaceans have become adjusted.

TIME NEEDED:

2 days

MATERIALS:

collecting jars
pill bugs
bright-colored nail polish or typing correction fluid

PROCEDURE:

1. Select a study site and mark its boundaries. Draw a sketch of the study site and label it "Day 1."
2. Determine the climatic conditions of the study site. Include air temperature, relative humidity, and moisture of the soil. Record this information on the Data Table.

DATA TABLE

Day 1		Day 2	
Temperature		Temperature	
Relative Humidity		Relative Humidity	
Soil Condition		Soil Condition	
Number of Bugs Collected and Marked (M_1)		Total Number of Bugs Collected (P_2)	
		Number of Marked Bugs Collected (M_2)	

3. Collect pill bugs by turning over rocks and logs. (Be sure to return the rocks and logs to their original positions.) Pill bugs are terrestrial gill-breathing crustaceans 1 cm-1 1/2 cm long and battleship gray in color. When picked up, they roll into a ball, which is why the are sometimes called "roly-polys" (see illustration). On your sketch, indicate areas where you found pill bugs.

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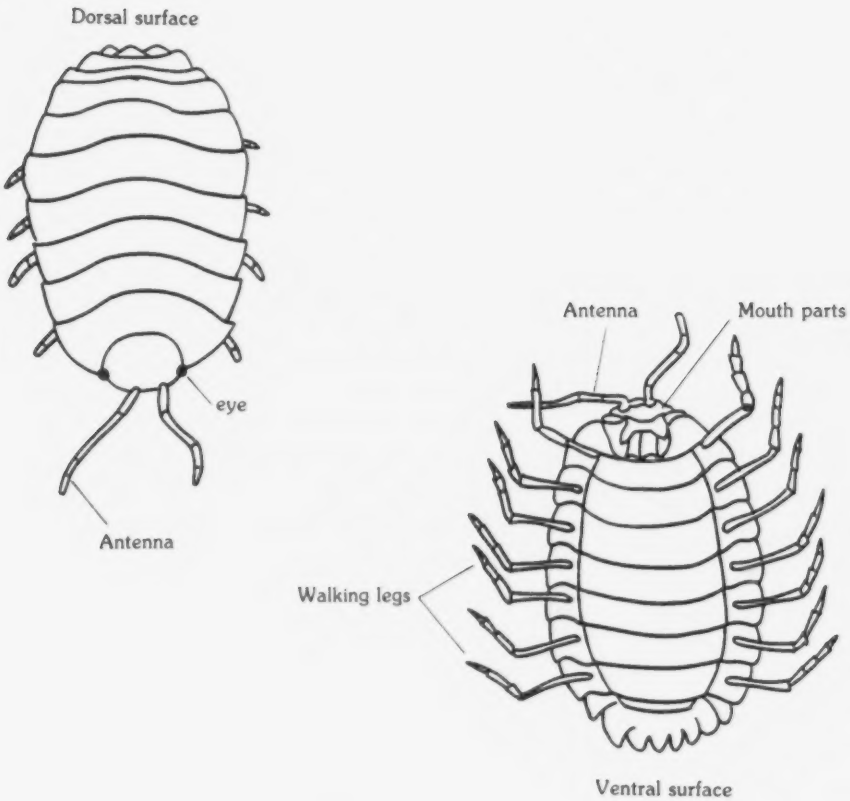

4. Using nail polish or correction fluid, make a mark on the back of each pill bug. (This mark will be shed as the pill bug sheds its exoskeleton, so no harm will result.) Count the number of bugs you have collected and record your results on your Data Table.
5. Release all of the pill bugs near the center of your study site.
6. The next day, determine and record environmental conditions again. Make a second sketch; then make a second collection like the first and indicate where the pill bugs are found on Day 2. Keep the marked bugs in your new sample and release the unmarked ones.
7. Count the marked bugs you have recaptured. Record this figure on your Data Table.
8. Return the marked bugs to the study site.

ANALYSIS:

1. Describe the environmental conditions that the pill bugs in your study seem to prefer. Were environmental conditions different on Day 2? Did the change seem to affect the number of bugs collected?
2. Estimate the pill bug population in your study site by using a simple ratio:

$P/M_1 = P_2/M_2$ or $P = P_2/M_2 \times M_1$

P = total population

M_1 = total marked on first day

P_2 = total collected second day

M_2 = number of marked bugs collected second day

In other words, in this method of estimation the proportion of the number of bugs found on Day 1 to the total number living at the site is assumed equal to the proportion of the number of marked bugs (bugs found on Day 1 and returned to the site) found on Day 2 to the total number of bugs found on Day 2.

OUR FINDINGS:

See Section V.

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DISCOVERING TIDAL POOLS

Eileen F. Ferrance

TOPIC:

Environmental Conditions and Population Distribution of Organisms in Tidal Pools

INTRODUCTION:

Tidal pools are shallow pools of water left behind by the outgoing ocean tide. Marine life that would otherwise not be found above the low-tide line thrives in tidal pools. Depending on their location, size, and depth, tidal pools may vary considerably in temperature and salinity. In this project, you will observe the characteristics of some tidal pools and the life they support.

TIME NEEDED:

1½ hours

MATERIALS:

ruler
hydrometer
thermometer
dip net
collecting jars or bags
field guide to marine life

Safety Precautions

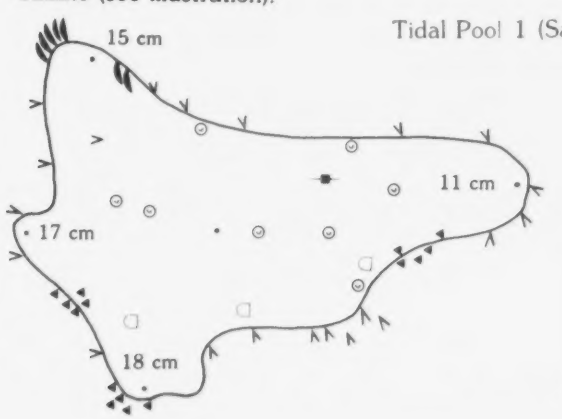
Adult supervision required. Read and copy the safety precautions at the beginning of this book. Wear sneakers or boots to assure good footing on slippery rocks.

PROCEDURE:

Plan to do this experiment at low tide. Make 3 additional copies of the Data Table below and bring them with you.

1. Choose a tidal pool near the waterline. On a plain piece of paper, draw a diagram of its outline (see illustration).

Tidal Pool 1 (Sample Diagram)



Barnacle
Hermit Crab
Periwinkle
Crab
Knotted wrack
Mussel

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Using your ruler, measure the depth at various places in the pool. Be sure to include the middle and four points on the edges. Record these measurements on your diagram and on a Data Table like the one shown.

DATA TABLE

Tidal pool_____

Location_____

Center depth_____

Side depths_____,_____,_____,_____

Temperature_____

Specific gravity_____

Salinity_____

Name of organism	Number found

2. Using the hydrometer, measure the specific gravity (density) of the water in the tidal pool and record it on the Data Table.
3. Using the thermometer, measure the temperature of the pool and record it on the Data Table.
4. Refer to the chart *Salinity Determination by Density* and determine the salinity of the pool you are studying by using your data on temperature and specific gravity. Record this information on your Data Table.
5. Collect plant and animal specimens from your pool. Use your field guide to identify them and list them on your Data Table. Sketch the location of these samples on your diagram of the tidal pool. On your Data Table, indicate the approximate quantity of each specimen present.
6. Return all specimens to their original homes.
7. Repeat the above steps with two additional tidal pools. Choose one that is near the high-tide mark and one that is halfway between the pools near the waterline and the high-tide mark.

ANALYSIS:

In written form, discuss the relationships you have found in the three tidal pools you have studied. Try to draw some conclusions concerning salinity, temperature, and type of organisms found.

OUR FINDINGS:

See Section V.

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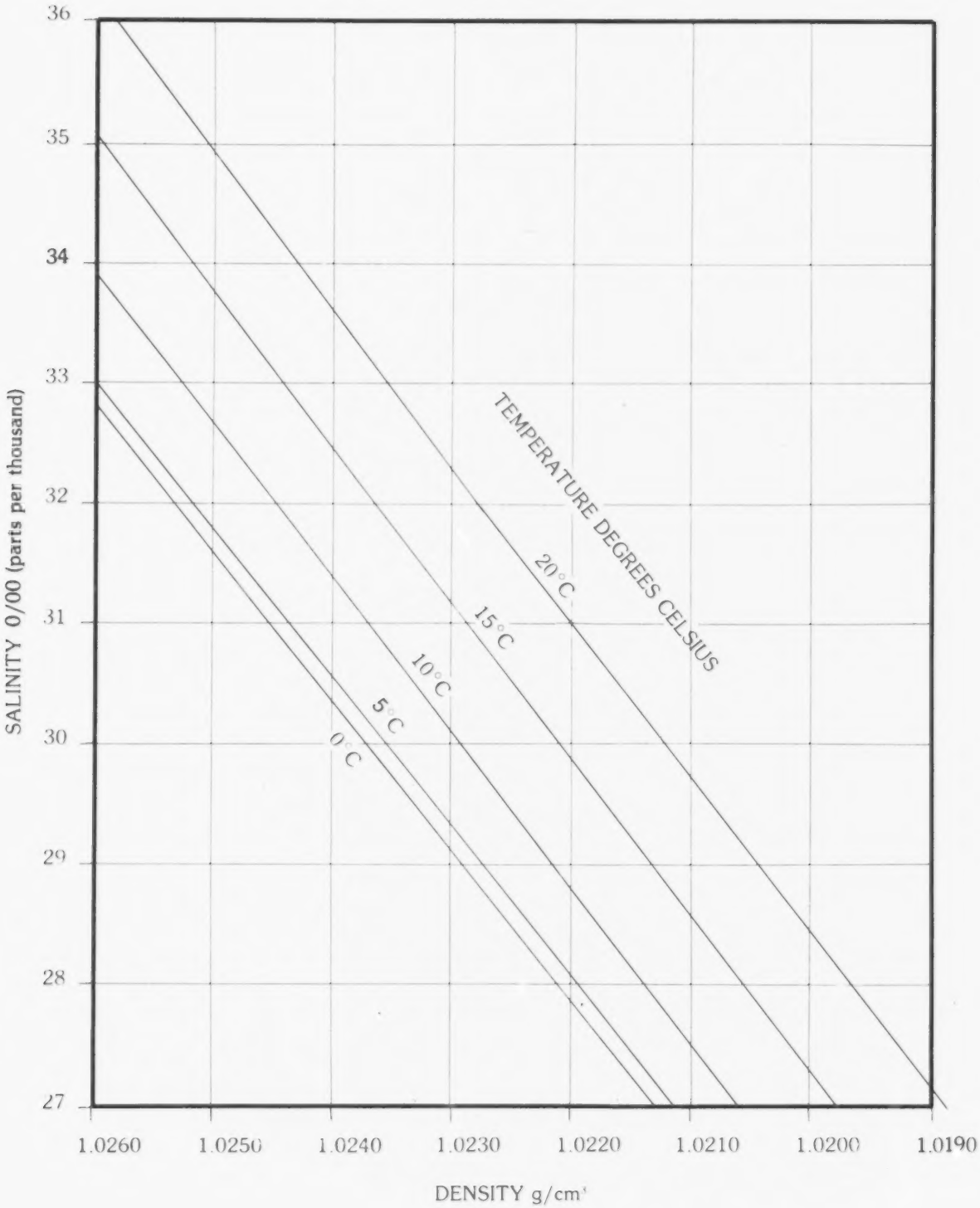
SALINITY DETERMINATION BY DENSITY



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ECOLOGICAL SURVEY OF A MARSH

Peggy L. Steffen

TOPIC:

Succession

INTRODUCTION:

A marsh is a long phase in the natural process, called succession, through which a pond or lake develops into a land area. As marshes grow older, they go through continuous stages of succession, experiencing changes both in their physical characteristics and in the animal life they support. In this project, you will observe the animal and plant life of a marsh or marshy pond in your area in order to determine its current stage of succession.

TIME NEEDED:

1-2 hours for preparation
6 hours to completion

MATERIALS:

large pole
boat
hip boots
2 lengths of sturdy rope (each long enough to reach from shore to middle of marsh)
grease pencil
masking tape
meter stick
wooden stakes
plastic milk bottle filled with sand or rocks
knife (to cut plant specimens)
large plastic bags
aquatic plant identification guide
binoculars
field guides to birds, insects, and mammals
plaster of paris
old bowls
cardboard or aluminum rings

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. Do NOT attempt this experiment alone. Have a partner along who will stay on shore in case of emergency. Make sure an adult is present to supervise. Check the depth of the marsh from a boat before you wade out, or check the depth as you go along, sticking a large pole in the mud in front of you before you take each step. Take one of the lengths of rope and tie one end of it around your waist and the other end around a tree on shore. Do NOT wade in water above your thighs. If the hip boots get flooded, they can pull you down.

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PROCEDURE:

Part A. Vegetation Survey

1. Mark off 1-m intervals on one of the lengths of rope and number each, using masking tape and grease pencils.
2. Tie one end of the marked line to a stake and drive it into the shore. Tie the other end to the bottle filled with sand or rocks. Using the hip boots for protection, wade into the marsh and drop the bottle several feet beyond the middle where the vegetation stops. Remember to follow the safety precautions listed above.
3. Walk along the line and at each 1-m interval label the distance and collect samples of the plants, both submergent (underwater) and emergent (above water) that are directly under the rope at that mark. Place the plants into a plastic bag numbered to correspond with each interval mark. Use one bag for each mark. Be sure to take small samples so that you disturb the marsh as little as possible.
4. Take the plants back to shore or home where you can identify (with the help of field guides) and count the plants. Record this information on the Data Table below.

DATA TABLE

1-meter Intervals	Total No. of Plants	No. of Emergents	No. of Submergents	Emergent Species Found	Submergent Species Found
1					
2					
3					
4					
5					
6					

Part B. Animal Life Surveys

1. Birds—Set up a time schedule to allow for several periods at different times of the day to observe bird life around the marsh. Take a pair of binoculars and a good field guide to birds to aid in identification. Keep a chart of the different species and numbers of each you have observed.
2. Amphibians and insects—You will find an abundance of insects both in the water and on shore. You might make observations on kinds rather than numbers of insects. Use a field guide to identify the insects. Another alternative is to make an insect collection. You will find directions in many science and nature books. Amphibians such as frogs and toads can be easily identified. Look for tadpoles also.
3. Mammals—The secretive ways of mammals will make observations difficult. An easy method is to make plaster tracks of the animals on the shore. You will need plaster of paris, old bowls for mixing, and cardboard or aluminum rings. Clear an area around the track and set up the ring around the track. Mix up just enough plaster of paris to cover the track. The plaster should be the consistency of soft mud so it will flow easily into the track and pick up a good imprint. Allow the plaster to dry completely. Remove the ring and wipe off the mud. Make a plaster track of each kind of animal near the marsh. Use a field guide to mammals to identify the tracks. Label each with species, date, and place.

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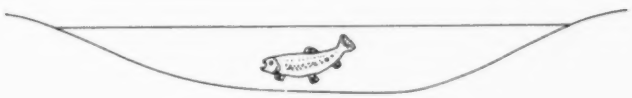
ANALYSIS:

1. Using your vegetation survey, animal observations, and the *Stages of Succession* diagram, decide at what stage of succession the marsh is. Is it young or is it becoming old? Is this area in danger of being destroyed? Can you contact anyone or do anything to save this area?
2. Prepare a slide show or poster containing diagrams, pictures, and your data to educate groups about the rich life of the marsh.
3. Find other marshes in your area and compare the data from several marshes.

STAGES OF SUCCESSION

Little or no vegetation, high O_2
Few species of wildlife, fish such as trout may become present
Little organic matter on the bottom
Low water temperatures

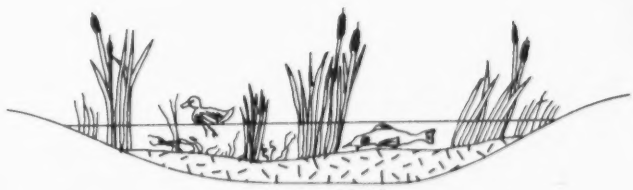


Clear Lake

Submergent vegetation present
Increased decomposer activity and bottom starts to accumulate sediment
Lowered O_2
More animal species such as ducks and fish-eating birds With them come predators such as coyote
Bass succeed the trout

Marshy Pond

Emergent vegetation appears. The bottom and edges of the water are now covered.
Heavy decomposer activity and thick bottom sediments
Carp and catfish now present
Heavy use by waterfowl and other wildlife
Algae growth prevalent and open water areas are scattered

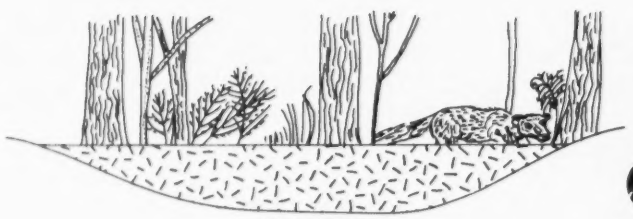


Mature Marsh

Water level low
Little O_2 because of decomposer activity
Little use by waterfowl

Boggy Meadow and Pond

Emergent vegetation gives way to bog grasses and sedges. Forest species appear
Land animals take the place of aquatics



Moist Forest

OUR FINDINGS:

See Section V.

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THE EFFECT OF COTYLEDON REMOVAL UPON PEANUT EMBRYOS

Dr. Murray Paton Pendarvis

TOPIC:

Plant Embryology

INTRODUCTION:

The cotyledon or seed leaf of a plant provides the embryological plant with a source of nourishment until the plant can become self-maintaining. Peanuts are classified as dicotyledones, which means that they possess two cotyledons. In this experiment you will study how removing a peanut's cotyledons or parts of a cotyledon affects its development.

HYPOTHESIS:

The amount of cotyledon removed is directly related to the embryonic development of a peanut.

TIME NEEDED:

7-10 days

MATERIALS:

viable peanuts (from a seed supply company or a local health food store)
resealable plastic bags
paper towels
scalpel or razor blade
water
magnifying glass
ruler
cardboard box

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Use scalpel or razor blade carefully when removing portions of the peanut cotyledon.

PROCEDURE:

1. Purchase enough viable peanuts to ensure that 100 individual undamaged raw peanuts can be used in the experiment.
2. Remove the shell from the peanut as well as the brown paper-like covering from the individual nut.
3. Divide the peanuts into five groups of 20.
4. Designate group 1 as the control group, group 2 as 25% removal, group 3 as 50% removal, group 4 as 75% removal, and group 5 as 100% removal.
5. Examine the peanuts; the pointed end contains the embryo and should be handled with care. The two halves of the peanut are called cotyledons. When you divide the peanut in half, only one cotyledon will contain the embryo. (See figure 1.)

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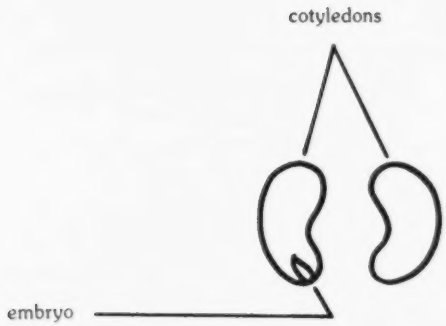

figure 1

6. Using a scalpel or razor blade and leaving the embryo intact, remove 25% of each of the peanuts in group 2 by removing half of the cotyledon on the side that does not contain the embryo. In group 3, remove 50% of each peanut by removing the entire cotyledon that does not contain the embryo. In group 4, remove 75% of each peanut by removing the cotyledon that does not contain the embryo and half of the cotyledon that does contain the embryo. In group 5, remove the embryo and discard the rest of each peanut. (See figure 2.)

7. Place each group of peanuts between two moistened pieces of paper towel.

8. Place the towels and peanuts in resealable plastic bags and seal them. Label the bags.

9. Place the bags in the a cold, dark place. A box in a corner away from sun or heat is good, or keep in an air-conditioned room if your are working in summer heat.

DATA TABLE

	% of Cotyledon Removed	Number of Seeds Germinated	Measurements and Observations
Group 1	Control 0%		
Group 2	25%		
Group 3	50%		
Group 4	75%		
Group 5	100%		

10. Check the peanuts daily for 7 to 10 days, observing for germination. If the towels seem to be drying out, moisten them again. Record the number of seeds germinated in each group on the Data Table.

11. Closely observe the growth of the embryos, using a magnifying glass and ruler. Record measurements on the Data Table.

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Group 1 Group 2 Group 3 Group 4 Group 5

figure 2

ANALYSIS:

1. What is the effect of cotyledon removal on germination?
2. Discuss the relationship between the percentage of the cotyledon removed and the development of the peanut embryo. Try to explain these results.

OUR FINDINGS:

See Section V.

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THE EFFECT OF SOIL pH ON PLANT GROWTH

Louis A. Ventura

TOPIC:

Acid Rain

INTRODUCTION:

You have probably read or heard about a pollution problem known as acid rain. Precipitation becomes acidic by absorbing pollutants in the air that come from automobile exhaust and industrial emissions. When it rains or snows, the acidic pollution is transferred to crops and forests. In this experiment, you will study the effects on plant growth of solutions of varying degrees of acidity. Your results should provide some insight into the possible consequences of acid rain.

TIME NEEDED:

2-4 weeks

MATERIALS:

1 package each—pole bean and radish seeds
20 lbs. potting soil
plant food
distilled water
graph paper
meter stick
Celsius thermometer (Celsius: range 15°-40°)
5 trays capable of holding 6 pots each
30 3-in. diameter plastic plant pots
shelf with fluorescent lamps attached 3 ft above (windowsill or greenhouse is fine)
pH testing paper capable of measuring each pH level from 3 to 11 (hydrion paper) or pH meter
100-ml graduated cylinder
automatic timer to shut off lights at night (optional)
1-gal. (4-l) solutions of each of the following prepared by teacher:
nitric acid at pH 3
nitric acid at pH 5
distilled water (pH 7)
potassium hydroxide at pH 9
potassium hydroxide at pH 11

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. The pH levels of 3 and 11 do not pose a threat of severe burns, but care should be taken not to spill these solutions or get them into the eyes. The concentrated acids and bases used to make the solution should be handled only by the teacher.

PROCEDURE:

Part A. Teacher Preparation

Dilute stock solutions of nitric acid and potassium hydroxide testing continuously with pH meter

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or pH testing paper to produce about 1 gal. each of solutions at pH 3, 5, 9, and 11.

Part B. Student Experiment

1. Clean pots and fill to ½ inch from the top with potting soil.
2. Plant 3 radish seeds in each of 15 pots. Plant the seeds about ½ in. below the soil surface. Label the pots as follows:

R1—pH 3
R1—pH 5
R1—pH 7
R1—pH 9
R1—pH 11
R2—pH 3
R2—pH 5
R2—pH 7
R2—pH 9
R2—pH 11
R3—pH 3
R3—pH 5
R3—pH 7
R3—pH 9
R3—pH 11

3. Plant 1 bean seed in each of the remaining 15 pots, labeling them B1—pH 3 to B3—pH 11 as above.
4. Fertilize each pot. Follow instructions on plant food container, adding exactly the same amount to each pot.
5. Each day until the seeds germinate water the soil of each pot well with distilled water. (Take care to give each pot the same amount of water.) This should take about 4 days to 1 week. If you are using artificial light, turn off lights at night throughout experiment.
6. When the radish seeds germinate, remove all but one seedling from each pot.
7. Once the plants have grown to over 1 cm in height, carefully measure and record the height of each seedling. Measure from the soil to the top of the stem, not to the tip of the top leaves. Record your results on the Data Tables on the line representing Day 1.

DATA TABLE

RADISH PLANTS	Height of stem in cm														
Day	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
	pH 3			pH 5			pH 7			pH9			pH11		
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															

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DATA TABLE

BEAN PLANTS Day	Height of stem in cm														
	B1	B2	B3	B1	B2	B3	B1	B2	B3	B1	B2	B3	B1	B2	B3
	pH 3			pH 5			pH 7			pH9			pH11		
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															

8. Water each pot daily for two weeks with 50 ml of liquid at the pH level indicated on the pot. Each day measure the height of each plant carefully and record results on the Data Tables.
9. After 14 days calculate the growth of each plant by subtracting the measurement at day 1 from the measurement at day 14.

ANALYSIS:

1. For the radish plants find the average amount of growth at each pH level (e.g., add the heights of R1-pH3, R2-pH3, and R3-pH3 and then divide by 3). Record your results in a table headed Mean Growth pH Levels. Do the same for the bean plants.
2. For the radish plants make a line graph showing the relationship between pH and growth. Put pH levels on the horizontal axis and growth in cm on the vertical axis. Make another graph for the bean plants.
3. Summarize your results for each type of plant. In what pH range did the plants grow best? At what pH levels was there the least growth?
4. Explain what your results might indicate about the possible dangers of acid rain.

OUR FINDINGS:

See Section V.

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STUDY OF A DUCKWEED POPULATION

Ronald J. Cisar

TOPIC:

Population Dynamics/Ecology

INTRODUCTION:

Plant growth is dependent on many variables, including space, available nutrients, and light. In this experiment you will observe and describe the effects of two independent variables—space and fertilizer concentration—on duckweed, a small, floating aquatic plant.

TIME NEEDED:

30-40 minutes' preparation
15 days' observation

MATERIALS:

2 large mixing containers
plant food
distilled water
teaspoon
400-ml beaker
4 small petri dishes (approximately 4 in. diameter and ¾ in. deep)
marking crayon
60 duckweed plants
tweezers
1 large petri dish (approximately 6 in. diameter and ¾ in. deep)
1 culture dish (8 in. diameter)
window with northern exposure or plant light
graph paper

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Handle plant food carefully. Wash your hands well after using it.

PROCEDURE:

1. Using the two large mixing containers, prepare the following fertilizer concentrations:

   weak fertilizer—½ teaspoon plant food/2500 ml of distilled water
   strong fertilizer—3 teaspoons plant food/2500 ml of distilled water

2. Pour 50 ml of distilled water into one of the small petri dishes, 50 ml of weak fertilizer solution into another small petri dish, and 50 ml of strong fertilizer solution into a third small petri dish. Label the dishes A, B, and C, respectively.
3. Using tweezers, put 10 duckweed plants into each of the 3 dishes and place each dish an equal distance from the light source. (See figure 1.)

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A
50 ml H_2O

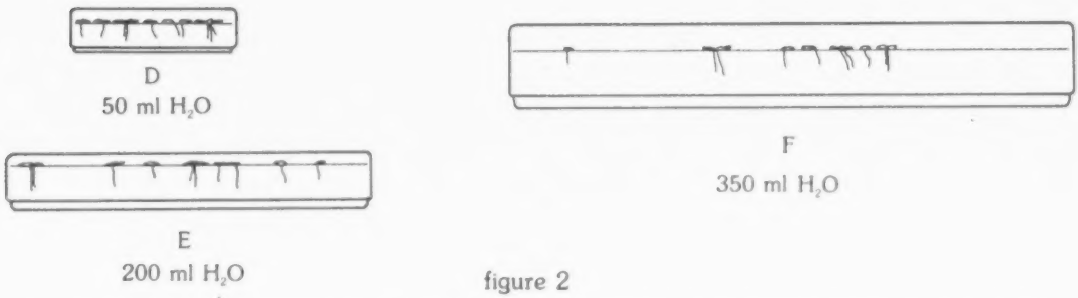
B
50 ml weak fertilizer

C
50 ml strong fertilizer

figure 1

4. Pour 50 ml of distilled water into the remaining small petri dish, 200 ml of distilled water into the large petri dish, and 350 ml of distilled water into the culture dish. (It is important that there is a significant difference in the diameter of each dish.) Label these D, E, and F.

5. Put 10 duckweed plants into each of these 3 dishes and place each dish an equal distance from the light source. (See figure 2.)



D
50 ml H_2O

E
200 ml H_2O

F
350 ml H_2O

figure 2

6. Every three days record on the Data Table the number of duckweed plants in each of the 6 dishes. Make sure the dishes do not dry out.

Note: Duckweed reproduces by a vegetative method called *budding*. It is an asexual form of reproduction in which small outgrowths, or buds, appear at the margins of the parent plant (see figure 3). They may break off upon maturity or remain attached, forming a colony (see figure 4). Be sure to count each new bud as a new plant.

Single plant

Budding

figure 3

Colony

figure 4

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DATA TABLE

	Dish contents	Day 1	Day 3	Day 6	Day 9	Day 12	Day 15
Environment	A. 50 ml H_2O						
	B. 50 ml weak fertilizer						
	C. 50 ml strong fertilizer						
Area	D. 50 ml H_2O						
	E. 200 ml H_2O diam. = 6 in.						
	F. 350 ml H_2O diam. = 8 in.						

ANALYSIS:

1. What effect did the weak fertilizer have on the duckweed population? Explain.
2. What effect did the strong fertilizer have on the duckweed population? Explain.
3. What was the purpose of petri dish A?
4. How do you interpret the results for dishes D, E, and F?
5. Using the data collected, make two line graphs. The first graph will show the effect of different environments A, B, and C. The second graph will show the effects of different amounts of space on dishes D, E, and F. There will be three lines per graph, one for each dish. Place the number of duckweed plants on the vertical axis and the number of days on the horizontal axis.
6. If a farmer fertilized his crops next to a farm pond, what would happen to the aquatic plants in the pond when it rained?

OUR FINDINGS:

See Section V.

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EFFECT OF FOOD SUPPLY ON FRUIT FLY DENSITY

Virgil A. Sestini

TOPIC:

Population Ecology

INTRODUCTION:

Population ecology is the study of how various factors such as food supply and density affect populations. In this experiment you will see how food supply affects the growth of the population of *Drosophila melanogaster*. These are the common fruit flies sometimes seen around bananas in the supermarket. They have been used in many scientific investigations because of their short life cycle (14 days) and because they have large numbers of offspring.

TIME NEEDED:

1-2 hours preparation
4-6 weeks to completion

MATERIALS:

8 small-mouth bottles or large test tubes
anesthetizing transfer bottle
FlyNap™ (available from Carolina Biological Supply Co.)
8 strips of paper that fit in small-mouth bottles or test tubes
hand lens or stereoscopic microscope
white index card (4 in. × 5 in.)
small camel's hair brush
50 Wild type and 50 White Eye-Yellow Body fruit flies (available from a scientific supply house)
cheesecloth and cotton, or aluminum foil
Drosophila instant media ingredients:
- instant mashed potatoes (powder not flakes)
- cornstarch
- cream of wheat cereal
- calcium propionate (mold inhibitor available from a scientific supply store)

yeast

Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

A. Preparing Media

1. Mix equal parts (by volume) of instant mashed potato powder, cornstarch, and cream of wheat.
2. To 100 parts of this mixture add five parts of calcium propionate.
3. Mix equal amounts of water and the dry media in the culture bottles. In two bottles or test tubes put ¾ in. of the mixture. In two other bottles put 1½ in. of the mixture. Add a few grains of yeast to each and stir vigorously.

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4. Allow the mixtures to sit for approximately 2 minutes. They will gel and are then ready for use.

5. Insert a small strip of paper into the media in each bottle while it is soft; this will provide additional surface for egg-laying and pupation (see figure 1).

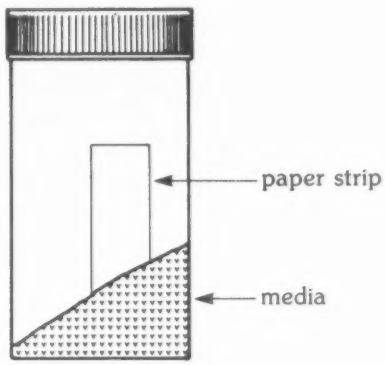

figure 1

6. Insert a cotton plug wrapped in cheesecloth or use aluminum foil to close the top of each bottle.

B. Introducing* Drosophila *to the media

1. Make sure there is no food in the experiment area.

2. Working quickly, use FlyNap™ to anesthetize the flies in the transfer bottle. An alternative method of anesthetizing fruit flies safely and inexpensively is to place the transfer bottle in the refrigerator just long enough to quiet the flies, that is, until all motion ceases.

3. To introduce the flies into the transfer bottle, turn the mouth of the bottle containing the flies away from the light, remove the plug, and place the mouth of the transfer bottle against the mouth of the other bottle. Hold the two bottles together, mouth to mouth, and turn the empty bottle toward the light. (See figure 2.) A gentle tap will start the flies moving. When the flies have entered the transfer bottle, close the latter with a stopper or cap. Soon the flies will become quiet and drop to the bottom of the bottle. The flies must not be kept in the bottle longer than 2 minutes, but you must make sure they are anesthetized or they will fly away. Remove any dead flies you find. (When anesthetized, the flies carry their wings normally, but when dead, they carry their wings vertically.)

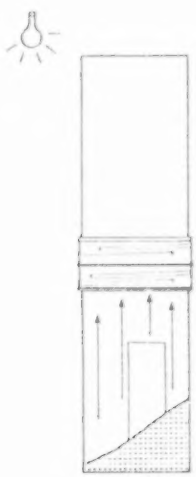

figure 2

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4. A few seconds after all the flies have ceased moving, remove the stopper and pour the flies out on a flat white index card, where they may be pushed into a narrow line and sorted for sex with a camel's hair brush and a hand lens. The sex of flies can be determined by noting the following:

   a) The male is noticeably smaller than the female and his smaller abdomen has a pointed posterior that terminates in a sort of "button."
   b) The black coloring on the rear end of the male's abdomen is more intense and extends around the sides to meet ventrally. The female's black coloring is in small lines across the tip of the abdomen, confined to the upper part, never meeting underneath, or sometimes not present at all.
   c) The whitish area on the underside of the male does not extend to the tip of the abdomen, but is reduced to a crescent-shaped area under the tip; near the concave anterior edge of this crescent is a small brown elevation, the male genitalia. In the female the white area extends under the abdomen, almost to its tip, to an acute angle, where it ends in a minute black speck on the ovipositor.
   d) The basal tarsal joint in the leg of the male bears a dark comb.

Caution: Sexes are scarcely distinguishable by color until the flies are a few hours old, the entire body being pale in newly emerged flies.

5. Introduce into the culture bottles the following distribution of each type of *Drosophila*:

   5 pr. in ¾-in. media (Wild)
   5 pr. in ¾-in. media (White Eye-Yellow Body)
   5 pr. in 1½-in. media (Wild)
   5 pr. in 1½-in. media (White Eye-Yellow Body)
   20 pr. in ¾-in. media (Wild)
   20 pr. in ¾-in. media (White Eye-Yellow Body)
   20 pr. in 1½-in. media (Wild)
   20 pr. in 1½-in. media (White Eye-Yellow Body)

6. Label each bottle.
7. Store flies at a constant temperature (30°C is satisfactory).

***C. Counting* Drosophila.**

At weekly intervals the flies should be anesthetized, counted on the white card, and replaced in the culture bottles. Record your findings on the Data Table. Continue this process for four to six weeks or longer if desired, making sure that the interval between countings is always the same.

WILD FRUIT FLIES

Date:	Week 1	Week 2	Week 3	Week 4
¾" media				
5 pr				
20 pr				
1½"				
5 pr				
20 pr				

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WHITE EYE-YELLOW BODY FRUIT FLIES

Date:	Week 1	Week 2	Week 3	Week 4
¾" media				
5 pr				
20 pr				
1½"				
5 pr				
20 pr				

ANALYSIS:

1. Comparing the ¾-in. and the 1½-in. food supply cultures, which has more flies at the end of the experiment?
2. For each culture, there was another bottle with the same conditions, the only difference being the number of fruit flies initially introduced. What is the difference between these bottles at the end of the experiment?

OUR FINDINGS:

See Section V.

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MAKE YOUR OWN YOGURT

Zoe A. Godby Lightfoot

TOPIC:

Beneficial Bacteria

INTRODUCTION:

Yogurt, which people have been making and eating for hundreds of years, is produced by bacteria. In fact, when you eat yogurt with active cultures in it, you are eating some live bacteria. All organisms, from people to bacteria, have a range of temperature in which they thrive—called the optimal temperature. People who make yogurt need to conduct trials like the ones in this experiment in order to determine the optimal temperature for the bacteria they wish to grow.

TIME NEEDED:

1½ hours for preparation
12 hours for incubation

HYPOTHESIS:

Yogurt grows best at a warm temperature.

MATERIALS:

liquid dishwashing detergent
soft clean towels
yogurt maker or wide-mouthed thermos
750 ml (approximately a quart) of 2% or 4% fat homogenized pasteurized milk
400-ml heat-resistant graduated beaker
250-ml beaker
metal pan
plastic pan
container of plain yogurt containing active yogurt cultures
100-ml beaker or small glass container
teaspoon
plastic wrap
hot plate, stove, or Bunsen burner and ring stand with wire gauze with ceramic center
Celsius thermometer
glass stirring rod
refrigerator or a 250-ml beaker in a cooler with ice

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Tasting the final product (the yogurt) is not recommended.

PROCEDURE:

Before you begin, make 3 copies of the Data Table.

Trial A: Control

1. Make sure all pieces of equipment to be used are absolutely clean by washing them thoroughly with warm water and detergent. Rinse thoroughly with warm water and dry with a clean towel.
2. Plug in the yogurt maker or warm the wide-mouthed thermos with boiling water.

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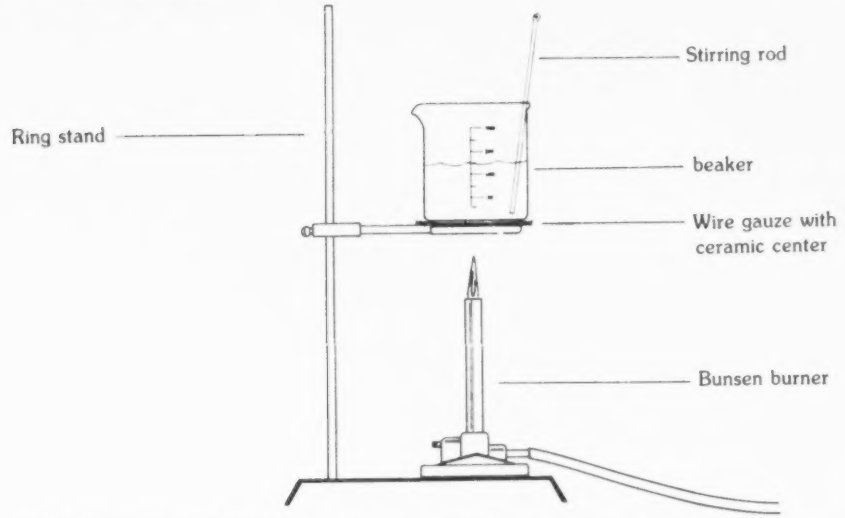
3. Measure out 250 ml of milk in a 400 ml graduated beaker.

4. Heat the milk to 82°C. If you are using a stove or hot plate, place the beaker of milk in a pan of water to heat. If you are using a Bunsen burner, set up the milk on the ring stand as shown in the illustration.



5. Cool the milk to 43°C by putting the beaker in a pan of cool water.

6. Put 4 level teaspoons of yogurt into a 100-ml beaker or a small glass container and *slowly* add about 25 ml of the 43°C milk until you have a thin mixture.

7. Add the mixture from step 6 to the rest of the warm milk and stir thoroughly. (You are adding the bacterial culture to the milk.)

8. Pour the milk into the yogurt maker jars or a warm thermos bottle for incubation. Cover the jars or screw on the stopper of the thermos to incubate for at least 12 hours.

9. Uncover and observe the jars or thermos of milk and write your observations on the Data Table below.

DATA TABLE

	Trial A	Trial B	Trial C
Consistency of mixture			
Smell of mixture			

Trial B: Incubation at a Low Temperature

Repeat the experiment, following the same steps as in A, except steps 2, 8 and 9. Use steps 2. 8 and 9 below instead.

2. Make space in a refrigerator, or put ice in a cooler.

8. Pour the milk into the yogurt maker jars or put into 250-ml beaker. Cover with plastic wrap. Then either refrigerate until the following day or leave in ice-filled cooler.

9. Uncover and observe the jars or beaker of milk and write your observations on the Data Table.

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Trial C: Adding the Bacterial Culture to Hot Milk

Repeat the experiment, following steps 1-4 from *Trial A*, but replacing steps 5-9 with those below.

5. Remove milk from heat, but do not allow it to cool. Proceed immediately to step 6.
6. Put 4 teaspoons of yogurt into a 100-ml beaker and *slowly* add about 25 ml of the 82° C milk until you have a thin mixture.
7. Add the mixture from step 6 to the rest of the 82°C milk and stir thoroughly.
8. Pour the milk into the yogurt maker jars or the warm thermos bottle for incubation. Cover the jars or stopper the thermos and incubate until the next day.
9. Uncover and observe the jars or thermos of milk and write your observations on the Data Table below.

ANALYSIS:

1. Compare the results of *Trials A, B,* and *C.* In which trial or trials was yogurt formed? What explanation can you give for these results?
2. In *Trial A,* why do you think the milk was first heated to 82°C and then cooled to 43°C?
3. What do you think would happen if you put the milk that was kept cool in step 8 into an incubator at 43° C for 12 hours? Why?
4. When people eat yogurt with "active yogurt cultures," they are eating live bacteria. What effect does the bacteria have on them?
5. If a Swiss-style yogurt without active yogurt culture was used in this experiment, what would the results have been? Why?

OUR FINDINGS:

See Section V.

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VINEGAR AND THE VINEGAR EEL

Juliana Texley

TOPIC:

Production of Acetic Acid by Living Organisms

INTRODUCTION:

Apple cider can become a complex microenvironment if allowed to age. The bacterium *Acetobacter* converts the cider's sugar into acetic acid (vinegar). Sometimes in old bottles of vinegar you can see a cloudy mass at the bottom. This is a fungal mass that often also contains *Turbatrix* (vinegar eels), microscopic nematodes that feed on the fungus and *Acetobacter*. In this experiment you will observe the relationship between the populations of *Acetobacter* and *Turbatrix* in acidifying cider, and explore the role of an abiotic factor in their growth: the presence of oxygen.

TIME NEEDED:

8 weeks

MATERIALS:

2 350-ml Erlenmeyer flasks
rubber stopper to fit flask
¾ l raw apple cider (unpasteurized if possible)
10 ml vinegar eel culture or aged vinegar
10-ml flask
stirrer
cotton wool
pH paper
microscope, slide, and coverslip
eyedropper
graph paper
2 pencils of different colors

Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

Vinegar eel (*Turbatrix*) at high magnification

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PROCEDURE:

Part A. Setup

1. Label the Erlenmeyer flasks "aerobic" and "anaerobic."
2. Put 300 ml of pure apple cider into each.
3. To each flask add 5 ml of solution from a well-stirred culture of vinegar eels or aged vinegar.
4. Put a rubber stopper in one flask to completely seal it. Put a piece of loosely wrapped cotton wool into the top of the other flask. (This will reduce the rate of evaporation but will allow air to go in and out of the flask.)

Part B. Measuring the Vinegar Produced

Vinegar is known chemically as acetic acid. As this acid is produced, it will decrease the pH of the solution. Thus, by using pH paper, we will be able to find the relative amount of vinegar produced. The lower the pH value, or the greater the acidity, the greater the concentration of vinegar. Measure and record on the Data Table the pH once a week for 8 weeks.

DATA TABLE

Week	pH	Average number of nematodes
1		
2		
3		
4		
5		
6		
7		
8		

Part C. Counting Vinegar Eels.

Each week, perform the following procedure for each culture.

1. Stir the culture, put a drop of it on a slide, and cover with a coverslip.
2. Focus the microscope on the fluid and change to medium power.
3. Count the number of nematodes that you see in that field of view.
4. Move the slide and count the number of eels in two different fields of view.
5. Find the average number of vinegar eels per field of view. Record this number on the Data Table.

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ANALYSIS:

1. Make a graph with time in days on the horizontal axis and pH levels on the vertical axis. Graph the changing pH levels of each bottle as a separate line in a different color on the same graph. Make another graph with time on the horizontal axis and the number of vinegar eels on the vertical axis. Again graph the results of both bottles.
2. How did the rate of change in pH in the oxygenated bottle compare with the rate of change in the unoxygenated bottle? How did their final pH levels compare?
3. How did the change in pH compare with the rate of reproduction of the vinegar eels? Did the vinegar eel population increase dramatically at any point, or was the rate of growth steady? Did the pH level change at a steady rate or did it slow down at any point? How do you explain the relationship between rate of vinegar eel reproduction and rate of vinegar production (indicated by low pH)? Note the odors of each bottle. Do you notice anything else in the closed flask?

OUR FINDINGS:

See Section V.

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VARIATIONS ON A HUMAN FACE

Donna Mae Jablecki

TOPIC:

Genetics

INTRODUCTION:

The Austrian monk Gregor Mendel determined the basic laws of genetics, the rules governing how traits are handed down from parent to offspring. A trait is passed down through genes, the basic unit of genetic information, with at least two genes, one from each parent, controlling its inheritance. Some traits are dominant, that is they prevent other traits from appearing. Some are recessive, these do not appear when a dominant gene is present.

For example, let us say that "tallness" is a dominant trait and "shortness" recessive. The following diagram, called a Punnett square, shows what might happen when a plant with two tall genes (a pure tall) is crossed with a plant with two short genes (a pure short).

T = tall
s = short

	T	pure tall T
s	Ts	Ts
pure short s	Ts	Ts

All the offspring would be hybrids, that is contain both a dominant and a recessive gene. Since we have determined that tallness is dominant, all offspring would look tall. But if we crossed these hybrids, we could get more varied results in the third generation as the following Punnett square shows.

T = tall
s = short

	T	hybrid s
T	TT	Ts
hybrid s	Ts	ss

It is important to note that the diagram holds true only when large numbers of offspring are represented. In this demonstration, we are going to discover what an offspring might look like if each parent is a hybrid for each characteristic and examine the possible variation that may result.

TIME NEEDED:

60-90 minutes

MATERIALS:

2 coins
drawing paper
pencil
colored pencils or crayons
scissors
glue

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PROCEDURE:

1. Choose a partner for this experiment. You and your partner will flip a coin to determine the facial characteristics of one of your "offspring." One of you will represent the father and the other will represent the mother. In each coin toss, heads represents a dominant gene and tails represents a recessive gene. In some cases a hybrid result will look like a mixture of the two traits. This is called incomplete dominance.

NOTE: Some of the traits are known to be inherited in the explained manner. The other traits were created to illustrate what *might* be happening. In actuality, inherited characteristics of the face are not as simple as has been demonstrated here. Several sets of genes may work together to produce a certain trait. Traits may be inherited separately or linked to one another.

2. First flip to determine the sex of the offspring. Only the father flips, as the father determines the child's sex.

Heads will be a boy.
Tails will be a girl.

Record your results on the Data Table.

DATA TABLE

Child's Name _____ Sex _____

Date of Birth _____

Phenotypic Characteristic	Father's Gene	Mother's Gene	Phenotypic Characteristic	Father's Gene	Mother's Gene
Face shape			Eyelashes		
Chin shape (1)			Mouth size		
Chin shape (2)			Lip size		
Cleft chin			Hapsburg lip		
Widow's peak			Dimples		
Hair texture			Nose size		
Hair color (4 letters)			Nose shape		
Eyebrows (1)			Nostril shape		
Eyebrows (2)			Nose tip		
Color of eyebrows			Ear and nose size		
Eye distance			Earlobes		
Eye size			Darwin's ear point		
Eye shape			Hairy ears		
Eye position			Freckles		
Eye color (4 letters)					

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3. Now flip for each of the facial characteristics that follow. Heads gives a capital letter, tails a small letter. See the illustrations section for the letters to use for each characteristic. For example, the first flip is for face shape. If your coin comes up heads, write *R* in the proper column next to face shape on the Data Table. If your partner's flip comes up tails, write *r* in his or her column on the Data Table. Then look at the illustrations. You will see that RR or Rr will produce a round face, while rr will produce a square face. Since your tosses resulted in Rr, this offspring will have a round face. Circle *round* in the Face shape section of the Checklist for Phenotypes. Continue in this way until you have flipped for all of the facial characteristics.

4. Now look at your completed Checklist for Phenotypes. Draw a picture of the offspring as he or she might look. You may also cut out the various parts of the face from the illustrations and assemble your face on a sheet of paper.

ANALYSIS:

1. If your whole class did this experiment, compare your drawings. How much variation is there in the offspring? Are you surprised by the amount of variation? Why?

2. Research Mendelian and population genetics in your biology textbook or an encyclopedia. Explain in what ways your random coin tosses approximate the actual chances of a child being born with given facial characteristics. Explain in what ways the experiment does *not* accurately reflect the chances of receiving given characteristics and what factors it failed to take into account.

Checklist for Phenotypes—circle your coin flip results.

Sex
- Male
- Female

Face shape
- round
- square

Chin shape (1)
- very prominent
- less prominent

Chin shape (2)
- round
- square

Cleft chin
- absent
- present

Hair texture
- curly
- wavy
- straight

Widow's peak
- present
- absent

Hair color
- black
- brown
- red
- blonde
- dark blonde
- pale blonde

Eyebrows (1)
- bushy
- fine

Eyebrows (2)
- not connected
- connected

Color of eyebrows
- darker than hair
- same as hair
- lighter than hair

Eye distance
- close together
- average
- far apart

Eye size
- large
- medium
- small

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Eye shape
- round
- almond

Eye position
- horizontal
- upward slant

Eye color
- dark brown
- brown
- green
- brown/green flecks
- gray blue
- dark blue
- light blue

Eyelashes
- long
- short

Freckles
- present
- absent

Mouth
- long
- average
- small

Lips
- thick
- thin

Hapsburg lip
- present (very protruding)
- present (slightly protruding)
- absent

Dimples
- present
- absent

Nose
- big
- medium
- small

Nose shape
- rounded
- pointed

Nostril shape
- rounded
- flared

Ear and nose size
- large ear, wide nose
- small ear, narrow nose

Earlobes
- free
- attached

Darwin's ear point
- present
- absent

Hairy ears (males only)
- present
- absent

Face Shape:

Round (RR, Rr)

Square (rr)

Chin Shape (1):

Very Prominent (VV, Vv)

Less Prominent (vv)

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Chin Shape (2): NOTE: Flip coins for this trait only if chin shape (1) was VV or Vv.

Round (RR, Rr) Square (rr)

Cleft Chin:

Absent (AA, Aa) Present (aa)

Hair Body:

Curly (CC) Wavy (Cc) Straight (cc)

Widow's Peak: The hair-line comes to a point in the center of the forehead.

Present (WW, Ww) Absent (ww)

Hair Color: Dark hair is dominant over light. To determine the color of the offspring's hair, assume there are two gene pairs involved. There are probably more. Flip your coin first to determine the genotype of the first pair of genes: (AA, Aa, aa). Now flip your coins again to determine the genotype of the second pair of alleles (BB, Bb, bb). Then match the genotype with the corresponding hair color by looking at the following chart:

If the genotype is:	Then the hair color is:
AABB	black
AABb	black
AAbb	red
AaBB	brown
Aabb	regular blonde
AaBb	brown
aaBB	dark blonde
aaBb	regular blonde
aabb	pale yellow blonde

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Eyebrows (1) Bushy (BB, Bb) Fine (bb)

Eyebrows (2) Not connected (NN, Nn) Connected (nn)

Color of Eyebrows: Darker than hair (HH) Same as hair (Hh) Lighter than hair (hh)

Eyes

Distance apart: Close together (EE) Average (Ee)

Far apart (ee)

Size: Large (LL) Medium (Ll) Small (ll)

Shape: Almond (wide) (AA, Aa) Round (narrow) (aa)

Slantedness (position): Horizontal (HH, Hh) Upward slant (hh)

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Eye Color: Dark eyes are dominant over light. To determine the color of the offspring's eyes, assume there are two gene pairs involved, one which codes for depositing pigment in the front of the iris and one which codes for depositing pigment in the back of the iris. Determine the genotype of the first pair (AA, Aa, aa). Then flip again to determine the second pair of genes (BB, Bb, bb).

If the genotype is:	Then the eye color is:
AABB	dark brown
AABb	dark brown
AAbb	brown
AaBB	brown/green fleck
AaBb	brown
Aabb	gray-blue
aaBB	green
aaBb	dark blue
aabb	light blue (hazel)

Eye Lashes:

Long (LL, Ll)

Short (ll)

Mouth:

Long (MM)

Average (Mm)

Small (mm)

Lips:

Thick (TT, Tt)

Thin (tt)

Hapsburg Lip:

Very Protruding (HH)

Slightly Protruding (Hh)

Absent (hh)

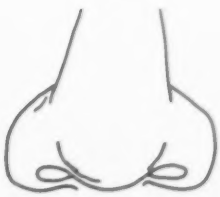
Dimples:

Present (DD, Dd)

Absent (dd)

Nose size:

Big (NN)



Medium (Nn)

Small (nn)

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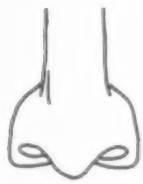
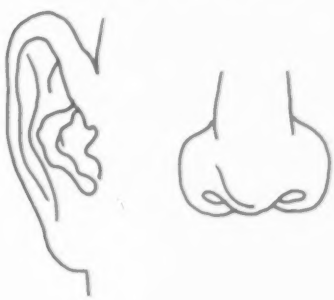
Nose Shape: Rounded (RR, Rr) Pointed (rr)

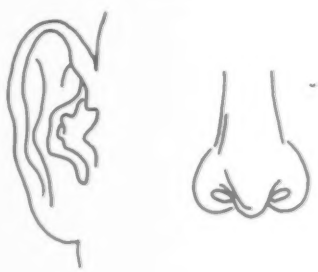
Nostril Shape: Rounded (RR, Rr) Flared (rr)



Note: Nose tip thickness and size of ears are almost always inherited together. In other words, thick nose tip and large ears are usually inherited together, but not always.

Flip coins first : (XX, Xx) large ears, thick nose (xx) small ears, narrow nose





To see if the traits have stayed together, flip again. If both tails come up and the results of the first flip called for big ears, make the ears small. If the results called for small ears, make them big.

Ear Lobes: Free (FF, Ff) Attached (ff)

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Darwin's Ear Point:

Present (DD, Dd)

Absent (dd)

Hairy Ears:

Note: occurs only in males (sex limited)

Absent (EE, Ee)

Present (ee)

Freckles:

Present (FF, Ff)

Absent (ff)

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THE DIVING REFLEX

Dorothea Allen

TOPIC:

Bradycardia: A Cardiovascular Defense against Asphyxia

INTRODUCTION:

The human body is able to respond to environmental and internal changes by readjusting its metabolic processes in order to survive. In this experiment you will determine what adjustments the body makes to defend itself against asphyxiation during an underwater breath hold.

HYPOTHESES:

1. The body has a natural defense against asphyxiation, which occurs when the breath is held under water.
2. This response will be different for athletes and nonathletes.

TIME NEEDED:

20 minutes to 1 hour depending on the number of participants

MATERIALS:

watch with second hand (or electronic pulse meter)
plastic dishpan or sweater box
water
elastic hair bands
paper towels

Safety Precautions

Adult supervision is required to make sure that students hold their breath only as long as they can do so without experiencing any discomfort or difficulty. Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

1. Choose a partner and practice measuring each other's pulse rate. If you are using a pulse meter, follow the instructions that accompany it. If you are using a watch with a second hand and counting the pulse beats yourself, practice locating your partner's pulse by applying light pressure with your index and third fingers to the inside wrist area directly below the thumb. (See figure 1.)

figure 1

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Feel the two-part rhythmically repeated pulse as a "thump" followed by a pause. Count the number of beats in 30 seconds, and multiply that number by 2 to determine the pulse rate in beats per minute.

2. Fill a plastic dishpan or sweater box three-fourths full of water, and place it on a tabletop.

3. You and your partner will take turns. First one of you will be the subject, and the other will measure and record pulse rates. Then you will trade places. Record your results on the following Data Table:

DATA TABLE

Name of Student	Indicate if Athlete (use star)	Pulse/Heart Rate at Rest	Average Pulse/Heart Rate During Breath Hold in Simulated Dive	Difference (+ or −) in Rates

4. First, measure the normal pulse rate of the subject while at rest. Record the figure on the Data Table.

5. Have the subject stand at the table, positioning his/her head, face down, above the pan of water (if necessary, secure long hair with an elastic band, pony tail fashion.) (See figure 2.)

figure 2

6. Have the subject take a deep breath and hold it while lowering his/her head toward the pan of water and completely submerging his/her nose and mouth. Subject should not exhale. CAUTION: BREATH HOLD SHOULD BE TERMINATED IF STUDENT EXPERIENCES ANY DISCOMFORT.

7. Measure and record the subject's pulse rate during a 30- second underwater breath hold. Then have the subject take his/her face out of the water. Have a paper towel ready for the subject to dry his/her face.

8. Allow the subject's pulse rate to return to normal.

9. Repeat the underwater breath hold and pulse rate measurement two more times.

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10. Record all three underwater pulse rates. Then add them up and divide by 3 to determine the subject's average pulse rate during an underwater breath hold. Subtract the average from the subject's pulse rate at rest. Record the difference on the chart.
11. Now repeat the procedure with yourself as the subject and your partner as the measurer/recorder.

ANALYSIS:

1. In what way if any does an underwater breath hold affect the pulse rate?
2. Do athletes and nonathletes respond in the same way to an underwater breath hold? (If neither you nor your partner is an athlete, compare your results with those of other students who are athletes.) What might account for any differences noted?
3. Would you expect the altered pulse rate to return to normal more quickly in an experienced diver or in a person who is afraid of water? Why?
4. How does the "diving reflex" offer a survival advantage to swimmers and divers? Think about what is actually measured by a person's pulse rate.

OUR FINDINGS:

See Section V.

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HOW GOOD ARE YOUR TASTE BUDS?

Richard N. Lord, Jr.

TOPIC:

Taste Thresholds

INTRODUCTION:

The sense organs of taste—taste receptors, or taste buds—are located on the tongue. People are generally able to identify four basic flavors in substances that come in contact with their taste receptors: sweet, salty, sour, and bitter. In this experiment you will investigate the sensitivity and location of your taste receptors for sweet and salty flavors to determine the lowest concentrations of substances dissolved in water that can still be tasted.

TIME NEEDED:

45 minutes

MATERIALS:

salt
table sugar
water (preferably distilled)
gram balance or food scale
10 plastic drinking glasses
stick-on labels or marking pen
100-ml graduated cylinder or measuring cup
10-ml graduated cylinder or pipette
cotton swabs
paper towels

Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

Part A.

Testing your taste threshold is easiest if you have a partner to administer the tests and record your responses.

1. Measure out 90 ml of water and pour it into a clean drinking glass. Add 10 g of sugar and stir until all sugar is dissolved. This will give you a 10% sugar solution.

3. Measure out 10 ml of this solution and pour it into another glass. Add 90 ml of water and stir. This will give you a 1% sugar solution. Continue this process until you have made 0.1%, 0.01%, and 0.001% concentrations.

4. Prepare each of these five concentrations with salt as well, starting with 10 g of salt for the 10% solution. Be sure to label all 10 solutions.

5. You will be sampling the solutions in 5 pairs (each consisting of a sweet and a salty solution of the same concentration). Assemble the pairs on a table with the labels turned away so only your partner can see them.

6. Begin by rinsing your mouth out with water and drying your tongue with a paper towel.

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7. Dip a clean cotton swab into the first unknown solution and smear it all over your tongue. If you can taste and identify either a sweet or salty flavor, have your partner mark down a + in the appropriate box on the Data Table. If not, have him or her mark a −.

DATA TABLE

Concentration	Taste	
	Sweet	Salty
10%		
1%		
0.1%		
0.01%		
0.001%		

8. Repeat steps 6 and 7 until you have gone through all the samples.
9. Copy the Data Table, rearrange the glasses in a new order, and test your partner's taste thresholds.
10. Identify the lowest concentration of each solution that you were able to taste.

Part B.

Now do the following test to see if you taste sweet and salty flavors in the same place in your mouth. Without showing you which solution is being tested, have your partner dip a swab into one of your two "threshold" solutions. Touch the swab to only *one* of three isolated places on your tongue: the very tip, the sides, or the very back. Identify the taste if you can, and have your partner make a note of it. If you identify the same taste more than once, does it seem more intense when you test with one part of your tongue? Have your partner note this, too. Rinse your mouth and dry your tongue.

2. Repeat this procedure 6 times until you have tasted both threshold solutions in all three places on your tongue, always without knowing which solution you are testing.
3. Switch places with your partner and use your partner's threshold solutions to test the location of his or her taste receptors.

ANALYSIS:

1. What is your taste threshold for sweet? For salty?
2. Were your thresholds for both flavors the same?
3. Were your partner's thresholds of sweet and salty tastes the same as yours? If not, how did they differ?
4. Based on the results of *Part B* of the procedure, do you think that your taste receptors for both sweet and salty are equally distributed over your tongue? If not, where does the sweet-sensitive area seem to be? Where does the salt-sensitive area seem to be? Were the results for this test the same for you and your partner?

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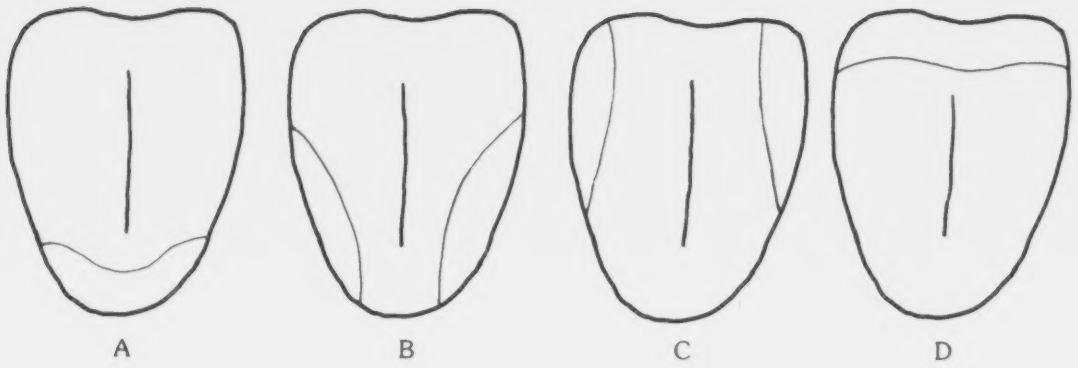

5. The four diagrams in the illustration show different taste-sensitive areas of the tongue. Which do you think is the sweet-sensitive area? Which is the salt-sensitive area?

OUR FINDINGS:

See Section V.

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HOW ARE THE SENSES OF TASTE AND SMELL RELATED?

Susan S. Plati

TOPIC:

Nervous System: Taste and Smell

INTRODUCTION:

The human body has sense organs that correspond to the five recognized senses: sight, hearing, taste, smell, and touch. The taste buds—small structures found mostly on the tongue—are the organ of taste. This experiment explores the relationship between taste and the other senses by asking subjects to identify tastes without the use of their eyes or noses.

HYPOTHESIS:

The sense of taste is partially dependent on other senses.

TIME NEEDED:

1 hour

MATERIALS:

knife
fruits and vegetables cut in 1 cm cubes:
raw potato, apple, cucumber, pear, watermelon, cantaloupe, onion (2 cubes of each food for each person in the experiment)
cutting board
toothpicks
paper plates
blindfold
glass of water (1 for each subject)

Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

1. Decide on your sample size for this experiment: the members of your family, a few friends, the members of your lab group-any of these could be your sample.
2. Cut fruits and vegetables into uniform pieces. Prepare 2 cubes, 1 cm on a side, of each food to be tested for each person in your sample. Eliminate seeds and peel. Thus, if your sample consists of 3 people and you are testing 5 different foods, you will need 30 cubes of food to complete the experiment. Place each kind of food on a separate plate. Serve the food with toothpicks. Cover the plates so the subjects cannot see the foods.
3. Tell your subjects that they will be tasting a number of fruits and vegetables, but do not let them know what fruits and vegetables they will be testing. Blindfold your subjects or have them

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close their eyes. Ask them to hold their noses while they sample the first cube of one of the foods you have prepared. Ask each subject to identify the food being sampled. Do not tell your subjects if they are correct until the end of the entire experiment. Record the answer on the Data Table. Place a Y in the box if the subject answers correctly and an N if he or she does not. Have each subject drink or rinse his or her mouth out with water after tasting each food. Repeat this procedure, one cube at a time. until all the foods have been sampled.

DATA TABLE

SUBJECT'S NAME	FOODS TESTED													
	POTATO		APPLE		CUCUMBER		PEAR		WATERMELON		CANTALOUPE		ONION	
	TRIAL NUMBER													
	1	2	1	2	1	2	1	2	1	2	1	2	1	2

4. Repeat the entire procedure with the second cube of the foods you have used. This time, blindfold your subjects but do not have them hold their noses. Serve the foods in a different order than in the first trial so the subjects cannot rely on previous experience for identification. Record the results by writing Y or N in the number 2 boxes below each food.

ANALYSIS:

1. Do your results indicate that the sense of taste depends on the other senses? Explain your answer, making specific references to your data.
2. Were some foods easier to identify than others? Give a hypothesis to explain any differences you noted.
3. Some people lose their sense of taste when they have a cold. Do your results indicate why this may happen?

OUR FINDINGS:

See Section V.

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THE RAW EGG MYSTERY

Susan S. Plati

TOPIC:

Osmosis and Diffusion

INTRODUCTION:

The cell is the basic building unit of all living organisms. The human body contains trillions of cells, each working to keep the body alive. Food moves into the cell and waste moves out of the cell through a process called diffusion. Molecules pass through the cell's permeable membrane, flowing from where they are more concentrated to where they are less concentrated. It is difficult to see this process in humans because human cells are so small. But in this experiment you will be able to see the process clearly using a large single cell—a hen's egg.

HYPOTHESIS:

Solutions separated by a membrane tend to become equal in concentration.

TIME NEEDED:

15 minutes for setting up
3-5 days for observation

MATERIALS:

raw hen's egg
vinegar (any kind)
tape measure, or string and ruler
jar, with lid, large enough to hold egg
water

Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

1. On Day 1, obtain a raw egg in its shell.
2. Measure the long and short circumferences (see the illustration) with a tape measure or a string and ruler. Enter your results on the Data Table under Day 1.
3. Place the egg in a jar and cover with vinegar.
4. Screw on the jar lid to prevent evaporation.
5. On Day 2, observe the egg without removing it from the jar. Record your observations.
6. On Day 3, carefully remove the egg from the vinegar and rinse it with tap water. Observe how the egg looks and feels. Record your observations. Measure the long and short circumferences, and record these measurements.
7. Remove the vinegar from the jar, thoroughly rinse out the jar, and place the egg inside.
8. Cover the egg with tap water and screw on the jar lid to prevent evaporation.

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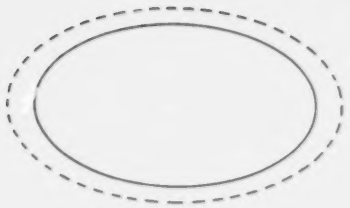
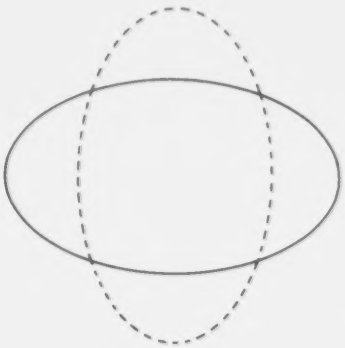
9. On Day 4, observe the egg and record your observations.
10. On Day 5, remove the egg from the jar. Measure and record the long and short circumferences. Observe and record how the egg looks and feels.



Long circumference



Short circumference

DATA TABLE

DAY	SHORT CIRCUMFERENCE	LONG CIRCUMFERENCE	OBSERVATIONS
1			
2			
3			
4			
5			

ANALYSIS:

1. How did the egg look and feel on Day 3? Try to explain what had happened to the shell of the egg.
2. How did the Day 3 measurements compare with the Day 1 measurements? Try to explain the change.
3. How did the Day 5 measurements compare with the Day 3 measurements? Try to explain the change.

OUR FINDINGS:

See Section V.

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HOW SIMPLE IS THAT SUGAR? TESTING FOR MONOSACCHARIDES

Ed Farrar

TOPIC:

Identification of monosaccharides

INTRODUCTION:

Carbohydrates are an important source of food energy. Many of the foods we eat contain carbohydrates in some form—starch, complex sugars (disaccharides or polysaccharides), or simple sugars (monosaccharides). Since our bodies' cells can only accept glucose, one of the monosaccharides, as their energy source, starches and all other sugars must be broken down to glucose by the digestive process. Glucose is present in varying concentrations in a number of foods that may surprise you. In this investigation, you will test different foods for the presence and concentration of glucose.

TIME NEEDED:

1 hour

MATERIALS:

water
12 small paper cups
12 stirring sticks
knife
urine glucose test strips (available at drugstores)
watch with second hand
at least 1 tsp. of each of the following:
- table sugar
- honey
- cola
- diet cola
- milk
- fruit juice
- steak sauce
- potato
- beet
- green vegetable, such as zucchini
- bread
- teaspoon

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Test strips are for use outside the body—do not put them in your mouth. Do not taste food samples.

PROCEDURE:

1. In the space provided on the Data Table, write "yes" or "no" to indicate your prediction of the presence of glucose for each substance.

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DATA TABLE

Food	Prediction	Results			Final concentration calculated
	glucose present	glucose present (yes or no)	color	concentration	
Beet					
Bread					
Cola (regular)					
Diet cola					
Fruit juice					
Green vegetable					
Honey					
Milk					
Potato					
Steak sauce					
Table sugar					
Water					

2. Place a teaspoon of each food into a separate paper cup. Rinse and dry teaspoon each time it is used. If the food is solid, chop and mash it so that it will mix with water. Add a teaspoon of water to each sample and stir with stirring stick.
3. In another paper cup put 2 tsp. of water.
4. Dip the reagent (blue) end of the test strip into the water. Remove it after 30 seconds. Compare the color of the strip with the color chart found on the side of the test strip container. Record whether glucose was present or not. Record the color and concentration it indicates.
5. Dip a fresh strip into each of the food samples. Compare the color of the strip with the color chart after 30 seconds. Record your results. A blue color indicates no glucose while colors ranging from green to brown indicate various degrees of glucose concentration.
6. Since you diluted each of the foods with an equal amount of water, each of the foods was tested in a 50% solution. The concentration indicated by the test should be doubled to give the concentration of the food itself. Write this number in the "Final concentration calculated" column of the Data Table.

ANALYSIS:

1. Did your experimental results match your predictions? Which foods contained the highest concentrations of glucose? Which had no glucose?
2. Why do you think you were asked to test the water?
3. Describe what must happen to a potato before it can be used by the cells of the body.

OUR FINDINGS:

See Section V.

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THE GREAT FRUIT JUICE CONTEST

Nevin E. Longenecker

TOPIC:

Vitamin C Concentrations

INTRODUCTION:

Vitamin C, also known as ascorbic acid, is vital for human health. It can be obtained by eating a balanced diet containing fruits and vegetables, especially citrus fruits. In this procedure, we will compare the vitamin C concentration of different fruit juices and note the effect of heat on vitamin C.

TIME NEEDED:

40 minutes for first test
20 minutes for each additional test

MATERIALS:

stove, hot plate, or gas burner
small pot
spoon or stirring rod
cornstarch
1000 ml distilled water
10 ml graduated cylinder
5 100-mg tablets of vitamin C (ascorbic acid)
2 100-ml amber-colored storage bottles (or bottles covered with paper)
500-ml beaker or jar
3 eyedroppers
tincture of iodine
100-ml beaker or jar
16 oz. fresh orange juice
juice from 2 other fruits

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. Do not taste any of the substances used in this procedure. Iodine is poisonous. Be sure not to contaminate fruit juice containers with iodine solution.

PROCEDURE:

Part A. Preparing the Solutions Needed for Testing

1. Make a paste of 1 g of cornstarch and 10 ml of distilled water. Then boil 90 ml of distilled water in the small pot. Remove the boiling water from the burner and stir in the starch paste. Mix well. If you are not performing the experiment immediately, refrigerate the solutions.
2. Crush a 100-mg tablet of vitamin C and add it to 50 ml of distilled water. Mix well. Add enough distilled water to produce a total of 100 ml. Store in a dark amber closed bottle in refrigerator. You will use this solution as your vitamin C standard.

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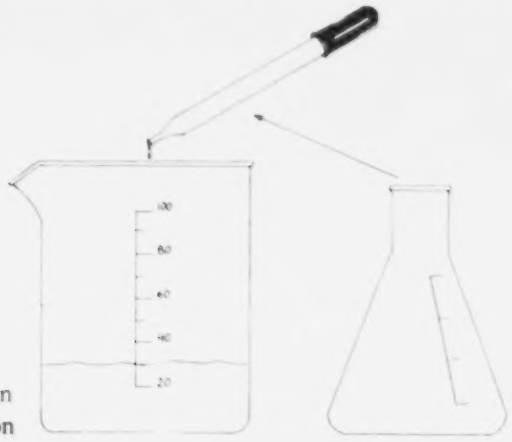
3. Place 200 ml of distilled water into a 500-ml beaker or jar. Add 10 drops of the tincture of iodine. Mix the solution well.

Part B. Titrating the Vitamin C Standard

1. Place 25 ml of the iodine solution you made in *Part A* into a clean 100-ml beaker.
2. Add approximately 2 ml of the 1% starch solution you made in *Part A*. (The exact amount is not critical, but 2 ml = 2 squirts of dropper.)
3. Now add the vitamin C standard drop by drop to this mixture until the color of the solution changes from black to clear. (See figure 1.) Record the number of drops used on the Data Table.

figure 1



25 ml of iodine solution
2 ml of starch solution

Vitamin C standard

Part C. Titrating the Juice Sample

1. Place 25 ml of the iodine solution into a clean 100- ml beaker.
2. Add approximately 2 ml of the 1% starch solution.
3. Now add the orange juice drop by drop to this mixture until the color of the solution changes from black to clear. Record the number of drops used on the Data Table.
4. Repeat steps 2-3 with other fruit juices. Record the number of drops needed on the Data Table.

Part D. Calculating Vitamin C Concentration

There is an inverse relationship between the Vitamin C concentration and the drops of juice used to reach the end point.

mg Vit C/100 ml juice =

$$\frac{\text{drops of vitamin C standard needed in } \textit{Part B} \times 100 \text{ mg}}{\text{drops of juice needed in } \textit{Part C}}$$

Calculate the vitamin C concentration of each juice using this formula.

DATA TABLE

Tested Substances	Number of Drops Needed to Change Color of Iodine Solution
Vitamin C standard	
Orange juice	
Juice 2: _____	
Juice 3: _____	
Orange juice heated to boiling	
Orange juice boiled 5 minutes	

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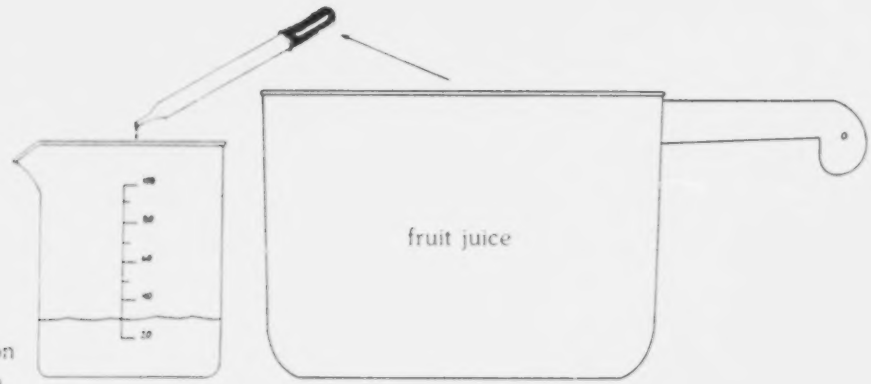
figure 2



Part E. Determining the Effect of Heat on Vitamin C Concentration

1. Heat 8 oz. of orange juice until it just starts to boil. Remove from heat and repeat *Part C*.
2. Boil 8 oz. of orange juice for 5 minutes and repeat *Part C*. Record your results on the Data Table.

ANALYSIS:

1. Which fruit juice had the highest concentration of vitamin C? Which had the lowest?
2. What happened to the vitamin C concentration of the orange juice when you heated it? Did the amount of heating have any effect? Explain.

OUR FINDINGS:

See Section V.

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DYE IT YOURSELF—NATURALLY!

Richard N. Lord, Jr.

TOPIC:

Extracting and Using Dyes from Plant Materials

INTRODUCTION:

Dyes are used to give color to textiles. They are made of colored matter that is used in a water-based solution. Natural dyes, obtained from natural sources such as plants, were used in the Middle East and China as long ago as 3000 B.C. Synthetic dyes, which are produced from chemical sources, were developed in the mid-nineteenth century. All dyes do not impart their colors to all textiles in the same manner. This is determined by the chemical affinity between the dye and the textile. In this experiment you will explore various natural dyes and their relationships to different fabrics.

TIME NEEDED:

approximately 1 hour for each dye, after all materials have been collected

MATERIALS:

natural dye materials:
- vegetables (onion skins, beets, carrots, spinach, etc.)
- fruits (strawberries, blueberries, grapes, etc.)
- twigs or bark from a tree
- brightly colored flowers
- lichens
- nut shells
- leaves

electric range or hot plate
enamel or glass saucepan with cover
wood, plastic, or glass rod for stirring
graduated beaker, cylinder, or measuring cup
strainer or other filtering apparatus
water
small glass vials or clear pill bottles
samples of unbleached natural fibers/fabrics:
- cotton squares (5 cm x 5 cm)
- linen squares (5 cm x 5 cm)
- silk squares (5 cm x 5 cm)
- wool yarn (tied in tassels)

Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

1. Select and obtain the natural materials and fibers/fabrics you wish to use in the experiment.
2. Place approximately 250 ml of water into a clean glass or enamel pan. Crush or break up one of the natural materials you have selected. The amount is not critical, but generally a larger amount of material will produce a more intense dye.
3. Cover and boil the mixture for 20 minutes.
4. Strain out the natural material and discard. What remains is the pure dye.
5. Pour dye into a clean glass or enamel pan and bring to a slow boil. As the dye starts to

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boil, add the fiber/fabric samples to it.

6. Boil for 20 more minutes. If water is in danger of boiling away, add more water.
7. Remove fiber/fabric samples. Rinse in clear water and dry.
8. Examine the samples to determine how the different fibers/fabrics responded to the dye. Record your results on the Data Table below.
9. Repeat steps 1-8 using other natural materials you have selected. If necessary, expand the chart to include more natural materials.

DATA TABLE

Name of Natural Material	Color of Natural Material	Color of Dye	Color of Dyed Cotton	Color of Dyed Linen	Color of Dyed Silk	Color of Dyed Wool
1.						
2.						
3.						
4.						

ANALYSIS:

1. Which dyes gave the fiber samples the deepest colors?
2. Did the dyes color the fiber samples evenly? Which dyes covered most evenly?
3. What color variations did you find when using a single dye on different fabrics?
4. Which dyes do you consider the best? Give reasons for your choices.
5. Colonial Americans used many natural materials for dyeing fabrics. Which of those you used do you suspect were used by pioneers? Give reasons for your answers.
6. Make a display showing each raw material, a sample of each pure dye in a small vial, and the dyed fibers/fabrics. These can be mounted on a board or set up as a table display. Be sure everything is completely and neatly labeled. Use your imagination to make a creative display.

OUR FINDINGS:

See Section V.

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HOW DOES A RED LEAF PRODUCE FOOD?

Otis Autry

TOPIC:

Photosynthesis; Paper Chromatography

INTRODUCTION:

In most plants, cells containing chlorophyll are spread throughout the leaves, giving them their characteristic green color. A second type of plant, a chimera, has leaves containing some cells with chlorophyll and some without. Those without do not contain pigment and are white. In these cases the chlorophyll cells provide food for the non-chlorophyll cells.

Many green leaves contain pigment colors that are not seen until the fall because they are masked by the chlorophyll. In the fall the tree extracts the chlorophyll from the leaves and sends it to the roots, thus allowing the other pigments to be seen. A few plants have leaves that are red, yellow, or orange all year long. In this project, you will use a technique called *chromatography* to determine if a red leaf contains chlorophyll.

TIME NEEDED:

1 hour

MATERIALS:

wire hook (made from paper clip)
rubber stopper (large enough to fit test tube)
scissors
chromatography paper
large test tube (25 x 200 mm)
spinach leaf
coin
solvent mixture (9 parts petroleum ether and 1 part acetone)
test tube support
red leaf (from a plant such as blood leaf) with no green coloration

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. Petroleum ether-acetone solvent is highly flammable. Do not expose it to heat or flames. Do not inhale fumes. Make sure the room is well ventilated.

PROCEDURE:

1. Make a J-shaped hook and push the straight end into the bottom of the stopper. Attach the strip of chromatography paper to the hook and lower it into the empty test tube. The paper strip should be trimmed so that it does not touch the bottom or the sides of the tube (see illustration), but should be as wide as possible within these limits.

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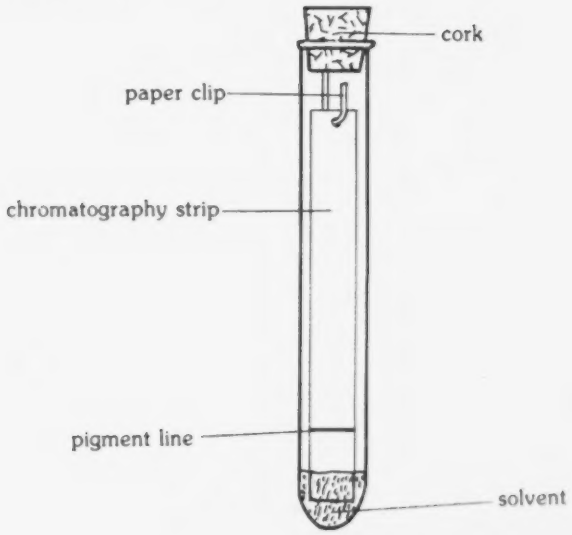

2. Remove the strip from the tube and place the spinach leaf about 2 cm from the end of the paper strip. Then roll a coin over the leaf so that a horizontal green line is transferred to the paper strip. This line contains leaf pigments and chemicals.
3. Add enough solvent to the test tube so that the end of the paper strip will be submerged, as in the illustration. Lower the strip into the tube. Be sure that the line containing pigments is not submerged. As the solvent moves up the strip, it will cause the pigments to separate out as different colors at different heights on the strip.
4. Place the tube in the test tube support. Do not disturb.
5. Watch the solvent as it moves up the paper strip. Record your observations.
6. Remove the strip from the test tube after about 15 minutes.
7. Let the strip dry and observe carefully. Make a sketch of the chromatogram. This is a typical chromatogram for a leaf containing chlorophyll:
   a) The blue-green band of pigments is chlorophyll *b*.
   b) The yellow-green band is chlorophyll *a*.
   c) The yellow band is xanthophyll.
   d) The yellow-orange band is carotene.
   Label the position of each pigment on your sketch.
8. Now repeat steps 1-7 using the red leaf.
9. Compare the chromatograms of the green leaf and the red leaf.

ANALYSIS:

1. How did the chromatograms of the red leaf and the green leaf compare? What can you conclude from this observation?
2. How does a red leaf produce food?

OUR FINDINGS:

See Section V.

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LEAVES CAN MAKE PHOTOGRAPHS

Warren B. Van Camp

TOPIC:

Photosynthesis

INTRODUCTION:

Photosynthesis is the process by which plants produce their own food. Plants use energy from sunlight to transform carbon dioxide, taken from the air, and water, taken from the soil, into carbohydrates: sugar and starch. These are the plant's source of food energy. Food that is unused by the plant is stored in the cells of its leaves. This demonstration, testing a sample leaf for the presence of starch, shows the importance of light in the photosynthetic process.

TIME NEEDED:

30-45 minutes, 3 days prior to lab
45 minutes to completion

MATERIALS:

geranium plant (or any other plant with large thin leaves)
index card
black-and-white negative of a photo with a great deal of contrast (small enough to fit plant leaf)
stapler
scissors
tape
fluorescent lamp
tincture of iodine solution
isopropyl alcohol
hot plate (or stove)
pyrex beaker large enough to fit plant leaf
saucepan
tongs
small bowl

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. Do not place the beaker of alcohol directly on the burner of the stove or hot plate—it might catch fire. Place it in a pan of boiling water. Do not leave unattended. Alcohol and iodine are poisons.

PROCEDURE:

1. Cut an index card in half. In one of the card halves, cut a hole large enough to create a frame for the negative.
2. Tape the black-and-white negative over the hole, and staple this card and negative combination to the upper surface of a leaf, without removing the leaf from the plant.
3. Staple the other half of the index card to the lower surface of the leaf (see ilustration).

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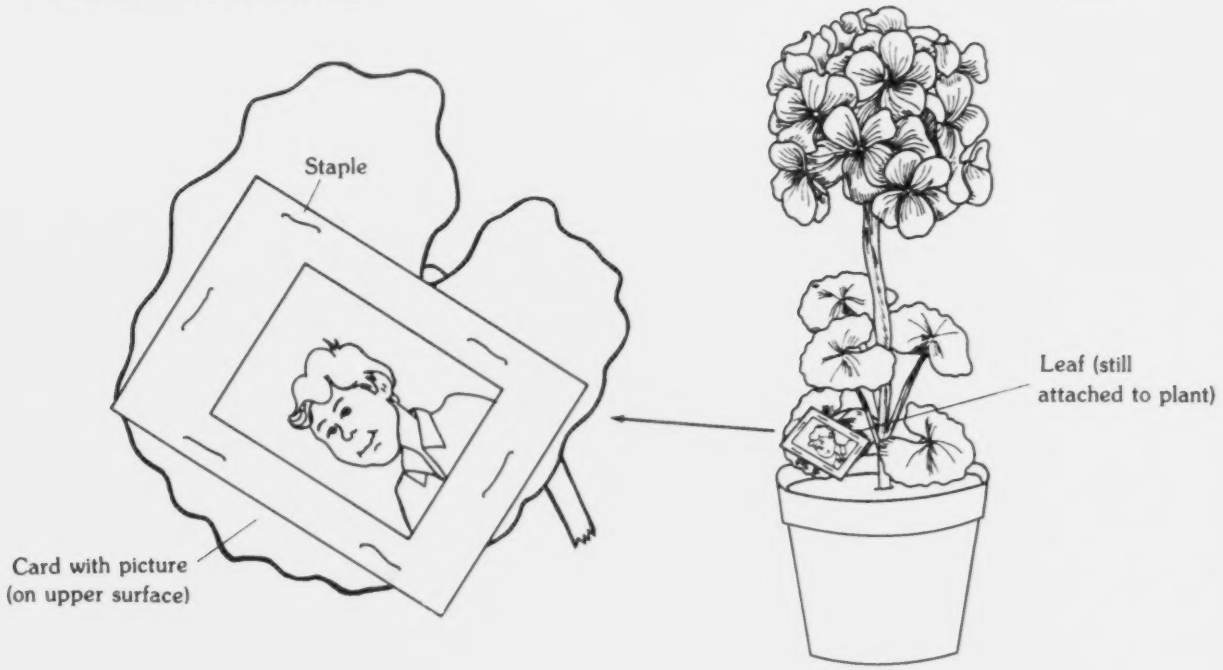

4. Place the plant in a dark cupboard for about 48 hours.
5. Remove the plant from the cupboard and place it under a fluorescent lamp for 26 hours.
6. Put about one inch of water in a pan and bring it to a boil.
7. Remove index card and film from the leaf. Remove the leaf from the plant and drop it in the boiling water for 30 seconds. Remove.
8. Put about 1 inch of alcohol in a beaker. Place the leaf in the alcohol and spread it out so that it is flat.
9. Put the beaker of alcohol in the pan of boiling water, making sure the beaker is stable. You may have to pour off some water if it does not sit comfortably. (CAUTION: Do *not* place the beaker of alcohol directly on the burner—it might explode and catch fire.)
10. Boil the leaf in the alcohol until all the green color has been removed from the leaf (about 9 minutes).
11. Remove the leaf with the tongs and place it in a bowl. Cover it with a solution of tincture of iodine for 5 minutes.
12. Use clean tongs to remove the leaf and rinse it in cold water. Record your observations.

ANALYSIS:

Describe what you saw on the upper surface of the leaf when you finished the experiment. Explain how you think this happened.

OUR FINDINGS:

See Section V.

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SPEEDING UP NATURE'S GREEN MACHINE

Chris L. Gentry

TOPIC:

Photosynthesis

INTRODUCTION:

Photosynthesis is the process by which plants produce their own food. They use energy taken from sunlight to transform carbon dioxide, taken from the air, and water, taken from the soil, into carbohydrates. A by-product of this process is oxygen. This surplus oxygen is emitted by the plant into the air. The rate of photosynthesis is governed by many factors, including temperature and light. In this experiment you will observe how these factors either speed up or slow down the reaction.

HYPOTHESIS:

The rate of photosynthesis can be altered by changing certain elements in the physical environment of the elodea.

TIME NEEDED:

24 hours for preparation
1 hour for each of 8 trials

MATERIALS:

250-ml flask
1-holed stopper to fit the flask
500-ml beaker
1 piece of aquarium tubing 150 cm long to fit snugly in stopper hole
lamp with 60-watt bulb
food coloring (green, red, or blue)
room temperature water (aquarium water is best)
ring stand
meter stick
tape (transparent and masking)
12 sprigs of elodea (*Anacharis*) aquarium plant (available in aquarium stores)
eyedropper
thermometer
ice chips
glass marker
petroleum jelly
baking soda (sodium bicarbonate [$Na\ HCO_3$])
gum or clay
watch or kitchen timer

Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

1. The overall equation for photosynthesis can be written as follows:

$$[6CO_2 + 6H_2O + \xrightarrow{\text{sunlight}} C_6H_{12}O_6 + 6O_2]$$

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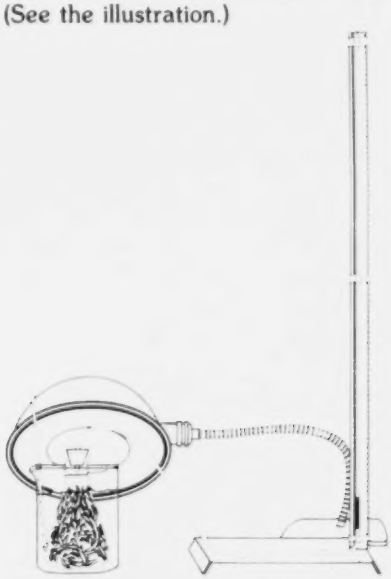
The amount of oxygen gas given off by a plant during photosynthesis can be used to determine the rate at which the process is occurring. Certain factors can affect the rate of oxygen production. You will be testing these factors by running this experiment a total of 8 times, first as a control and then trying each variation in step 19. You may want to assemble a team of people for this experiment to help with all the variations.

2. Let 12 sprigs of elodea sit in room temperature water under a lamp overnight before beginning the experiment. Use this same water the next day in step 5.
3. Place enough elodea in a flask so that the flask is very full of plant matter. About 6 full-size sprigs should do. Bend and coil the plants as necessary but do not break the stalks. Save the remaining plants in case you need them later.
4. Place the stopper in the flask and mark a line 5 mm below the bottom of the stopper.
5. Take off the stopper and fill the flask to the line with room temperature water.
6. Place the flask in the beaker filled with 250 ml of room temperature water.
7. Tape the meter stick to the ring stand with transparent tape.
8. Tape the 150-cm tube to the meter stick securely. Keep the top end of the tube even with the top of the meter stick. (See the illustration.)



9. Using the eyedropper, place a 5 cm length of colored water in the 150-cm tube without allowing any air bubbles to get in. To do this, put a thumb over the bottom of the tube and drop colored water in the top end with the eyedropper while slowly releasing the thumb to allow colored water to fall about halfway down the tube. This is a tricky thing to do, and it may take a few tries. The bit of colored water should be in one "solid" piece in the tube. If it is broken by air bubbles, it may make your measurements uneven. If there are air bubbles, blow the water out and start again.
10. Being careful so as not to break up or lose the colored water in the tube, place the other end of the tubing in the stopper. Use petroleum jelly to help slide it in. If the tubing is loose in the hole, pack gum or clay around it on top of the stopper so no air will leak.
11. Place the stopper in the flask and tape securely with masking tape. Be careful not to lose the colored water in the tube. *No air must leak.*
12. Note the level of the colored water on the stick (in mm). This will be a "zero reading."
13. Place the lamp 5 cm away from the flask.
14. Do not let the water temperature in the surrounding beaker get above 30°C. Use ice chips to cool it down.
15. Read the level of the colored water in mm at the end of 5 minutes and record.
16. Continue recording the results every 5 minutes for 30 minutes.
17. Calculate the rise in mm/min. Record the results.

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18. Graph the rise in mm/min. for each 5-minute time period.
19. Repeat the experiment 7 times, using one of the following variations each time. You can use the same plant sprigs for all the trials if you perform the sodium bicarbonate trial last. Otherwise, use different plants for that trial.

Colder water in beaker (5-10°C) with lamp at 5 cm.

Warmer water in beaker (35-60°C) with lamp at 5 cm.

Lamp at 10 cm.

Lamp at 15 cm.

No lamp.

No lamp, flask covered with foil

5% sodium bicarbonate ($NaHCO_3$) at room temperature in flask instead of water, with lamp at 5 cm (sodium bicarbonate is a source of CO_2). Make the solution by mixing 1 teaspoon of baking soda into 100 ml of water. Be sure the water is the same temperature as the water you used in your original trial.

ANALYSIS:

1. Briefly explain the technique used to measure the rate of photosynthesis in this experiment.
2. Did the rate of photosynthesis change when the light source was moved closer? When it was shut off? Describe all changes and explain these results.
3. Did the rate of photosynthesis change with the other variations? Describe all changes and explain these results.

OUR FINDINGS:

See Section V.

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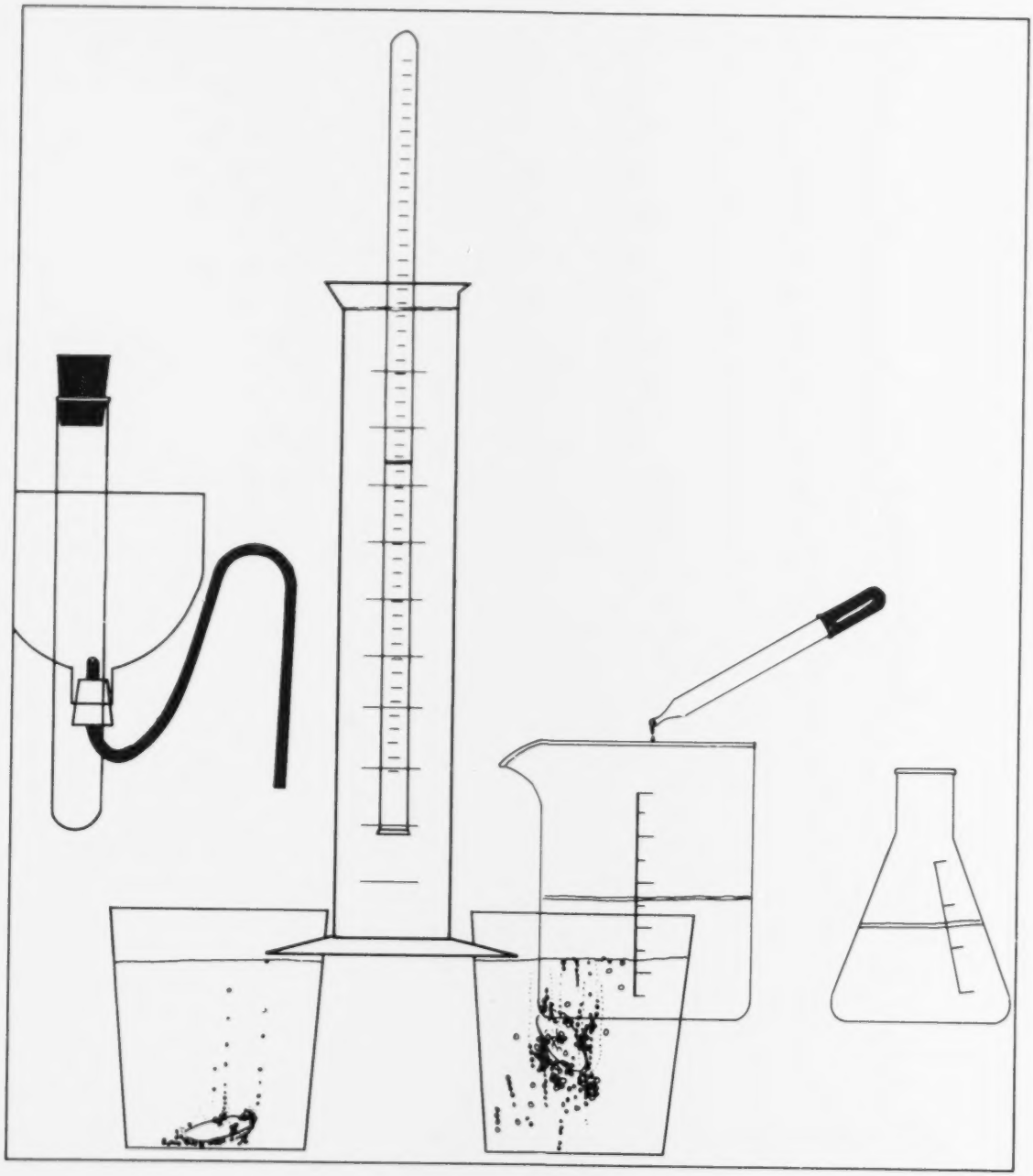
III.
PHYSICAL SCIENCE/ CHEMISTRY



TESTING POWERS OF OBSERVATION

Jim Cusker

TOPIC:

Scientific Observation and Analysis

INTRODUCTION:

One of the most powerful skills of scientists is their ability to make accurate, concise observations. To do this well, they must use all of their senses. This activity helps you practice your observation skills and demonstrates the limits of observation.

TIME NEEDED:

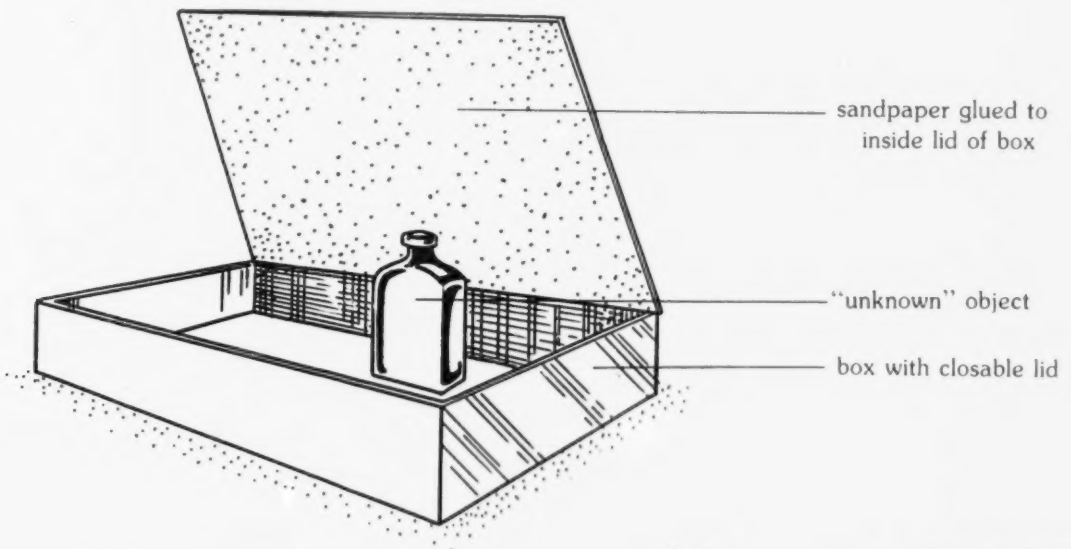
30 minutes

MATERIALS:

small cardboard or wooden box with lid (A box painted a solid color works well.)
sandpaper
glue
small cylindrical object such as a glass paint bottle or a child's wooden block

PROCEDURE:

1. In an area where no one can observe you, glue sandpaper to the inner surface of the top or bottom of the box.
2. Place the cylindrical object inside the box.



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3. Tell your friends to take out a pencil and a sheet of paper. Explain that they should observe your demonstration and record their observations.
4. First, hold up the box without shaking it. Ask your friends to write as complete a description of the box as they can. Give them a few minutes to do this.
5. Now shake the box so that your friends can hear the object inside. Tell them to listen as you move the box so that the cylinder rolls and slides along each surface. Ask them to guess what the object inside the box is like, based on what they hear. Can they tell what shape, size, and density it has? Can they tell what its surface is like?
6. Before you open the box, have your friends share their guesses about the object inside. Then open the box and show them the object. Discuss any wrong guesses and how your friends may have been misled. Then have everyone write answers to the following questions.

ANALYSIS:

1. Which of your senses did you use in this activity?
2. How accurate was your description of the box? Did you include its size, shape, color, and what you thought it was made of in your description? How might you improve your powers of visual observation? What tools might help you? Could you have used any other senses to help you write a better description?
3. How accurate were your conclusions about what was in the box? Did others include details that you missed? Why did you miss these details? Were any of your conclusions wrong? Why were you misled?
4. Did the presence of the sandpaper surface inside the box lead you to any false conclusions? If so, what lesson can you draw from this?
5. What details about the object in the box were impossible to deduce, given the limits of the experiment? Why is it important to realize the limitations of any experiment?

OUR FINDINGS:

See Section V.

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SEEING INVISIBLE COLORS

Edward C. Keller III

TOPIC:

Paper Chromatography

INTRODUCTION:

Although we "see" many colors, our eyes actually respond to only primary colors—red, blue, and yellow. We develop different colors by mixing different proportions of these three colors. Scientists use a process called paper chromatography to separate the primary colors that combine to produce the great variety of colors found in the world. In this experiment, you will apply this process to both natural and artificial colors.

HYPOTHESIS:

Most of the colors we see are really made up of a mixture of two or three primary colors.

TIME NEEDED:

1 hour

MATERIALS:

2 paper coffee filters
small paper cup
scissors
isopropyl rubbing alcohol
paper towel
felt-tip pens or markers (several different colors)
flower petals (several different colors, large petals work best)
green leaf

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Isopropyl rubbing alcohol is poisonous and flammable. Do not drink it. Keep it away from flame.

PROCEDURE:

Part A

1. Place a coffee filter flat on a hard surface. Using your scissors, cut the largest square possible out of the round filter.
2. Cut this square into strips ½ inch wide and put them into a pile.
3. Using a felt-tip pen or marker, place a ¼-inch wide dot of ink ½ inch up from each end of the strips. (See figure 1.)
4. Repeat Step 3 until you have dots of all the ink colors you want to investigate, each on a separate strip of filter paper.
5. Fold one end of each strip so that it will fit over the lip of the paper cup and so that the other end just touches the bottom of the cup. (You may have to cut the cup if the strip is not long enough to reach the bottom. See figure 2.)

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6. Remove the strips from the cup and pour no more than ¼ inch of isopropyl rubbing alcohol into the cup.
7. Carefully place the filter paper strips on the cup, making sure that the dots of ink do not touch the alcohol. If you are very careful, you can place many strips on the cup at the same time. Allow a little space between them.
8. Allow the alcohol to move up your filter paper strips. The longer you wait, the higher it will move.
9. After 15 minutes, remove the strips and place them on a paper towel to dry. When the strips have dried, observe them and record your observations.

figure 1

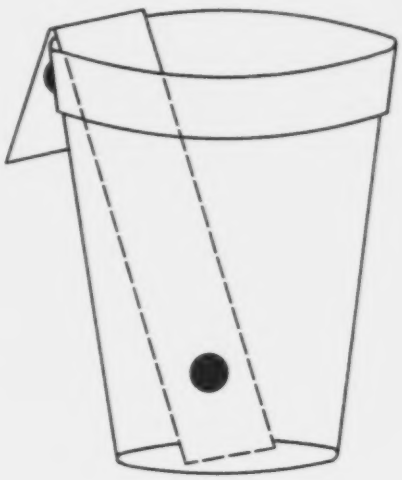

figure 2

Part B

Now repeat the experiment, using flower petals and a green leaf instead of felt-tip pens to provide the colors. In order to get the plant pigments onto the filter paper strips, place a leaf or flower petal on top of each strip and, using a hard object such as a pen cap, push down on the leaf or petal until a ¼-inch wide dot of pigment appears on the strip about ½ inch up from the end.

ANALYSIS:

1. Which ink colors separated into different colors on the strips? Which did not? How can you explain this?
2. Which plant pigments separated into different colors on the strips? Which did not? How can you explain this?

OUR FINDINGS:

See Section V.

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FINGERPRINTING

Mark T. Allen

TOPIC:

Scientific Observation / Individual Identification

INTRODUCTION:

Fingerprinting is the main method of identifying an individual with absolute certainty. No two individuals have ever been found to have identical fingerprints. In this procedure, you will demonstrate this fact while increasing your powers of observation.

TIME NEEDED:

40 minutes

MATERIALS:

- black ink pad
- several sheets of white typing paper
- glass jar with lid
- 2 camel's-hair paintbrushes
- bottle of carbon powder (Charcoal capsules, available at a pharmacy, may be substituted.)
- roll of ¾-in. transparent tape
- magnifying glass
- tweezers
- 2 grams iodine crystals (You can obtain this from a chemistry lab or a chemical supply company.)
- 3 in. x 3 in. piece of clean white paper that no one has touched

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. Use extreme caution when working with iodine crystals. Handle them with the tweezers. Work in a well ventilated area and do not inhale iodine fumes. Do not touch the crystals or place them near your mouth or eyes.

PROCEDURE:

1. Fingerprints are classified according to the pattern they form and are placed in one of the following three groups: the arch, the loop, and the whorl. While not a distinct group, some fingerprints appear to be a combination of two of the three standard classifications, such as the arch and loop. Study the examples in the illustration below.

Arch Loop Whorl Arch and Loop

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2. Have several volunteers take turns placing one finger on the ink pad and then pressing the finger onto a sheet of typing paper. This will leave an image of the fingerprint on the paper. Compare the prints to the ones illustrated and classify each as either arch, loop, whorl, or combination.

3. If you are using charcoal capsules, break open several capsules and mix the powder. Carefully grab a glass jar, making sure you leave your fingerprints upon its surface. Dip a small camel's-hair paintbrush in carbon powder or charcoal powder and gently apply the powder to the glass surface. You should see the image of your fingerprints in black. Carefully take three pieces of tape and press each piece against a different one of your powdered prints. Slowly lift the tape and press each against a clean sheet of typing paper. Use the magnifying glass to study the fingerprint patterns. Sketch these patterns in the boxes below and classify each print.

Print #1

Type:_____

Print #2

Type:_____

Print #3

Type:_____

4. Using tweezers, take the 3 in. x 3 in. piece of white paper and lay it on top of a table. Press down on the paper with your thumb, using enough force to leave a print. Carefully remove your thumb from the paper. Next, pour 2 grams of iodine crystals into the jar that you used earlier. Be careful not to inhale the iodine fumes or to get the iodine in your eyes or mouth. Replace the lid on the stock jar of iodine crystals. Using tweezers, pick up the piece of paper containing your thumbprint and place it in the jar containing the 2 grams of iodine crystals. (Try to keep the crystals from touching the paper; you could suspend the paper in the jar, using a piece of tape to secure it to the lid.) Place the lid on the jar and allow the iodine vapors to react with the paper. In 5 to 8 minutes you should see a purplish brown thumbprint. Using tweezers, remove the paper from the jar and replace the lid. Use the magnifying glass to study the thumbprint. Sketch the print in the box below and classify it.

Print #4

Type:_____

ANALYSIS:

1. Which fingerprint types did you identify?
2. Try to explain how carbon or charcoal powder reveals fingerprints.
3. Why do you think iodine vapor rather than carbon powder was used on the porous paper placed in the jar?
4. Try to explain how iodine vapor reveals fingerprints.

OUR FINDINGS:

See Section V.

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CREATING CLAY FOR TESTING

JoAnne Dombrowski

TOPIC:

Physical Change vs. Chemical Change
Mixtures vs. Compounds

INTRODUCTION:

A *physical change* is a change in matter in which the individual molecules of the substance(s) involved are not changed. Water freezing into ice is an example of a physical change. Although the substance has changed from a liquid to a solid, each individual molecule is still the same as it was before the change. The change can easily be reversed by allowing the ice to melt back into water. A *chemical change* is a change in matter in which the molecules of the substance(s) undergo a transformation into a different kind of molecule. Metal rusting is an example of a chemical change. Some of the molecules of the metal have changed into entirely different chemical substances and cannot be reversed to the original substance. A combination of substances resulting from a physical change is called a *mixture*. A combination of substances resulting from a chemical change is called a *compound*. In this experiment you will make clay and differentiate between the two types of change.

HYPOTHESIS:

Clay is a mixture.

TIME NEEDED:

30 minutes for main body of experiment, several days for final observation

MATERIALS:

1 small cooking pot
measuring spoons (teaspoon, ¼ teaspoon, tablespoon)
measuring cup
stove or hot plate
apron
potholder
stirring spoons
2 eyedroppers
cream of tartar
flour
salt
cooking oil
water
tincture of iodine
aluminum foil
ink marker
hand-held magnifying lens
paper towels
facial tissue

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Iodine is poisonous. Do not put it into or near your mouth or eyes. It may stain clothes or skin, so wear an apron. Do not eat or throw the clay.

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PROCEDURE:

1. Tear off 12 in. of foil.
2. Using an ink marker, draw a Test Sheet, like the one shown below, on the foil.

TEST SHEET

	Flour	Cream of Tartar	Salt	Water	Oil	Clay
Hand Lens						
Add Iodine						
Add Water						

3. Make another copy of the Test Sheet on a plain sheet of paper. This will be your Data Table for recording your observations.
4. Place ¼ teaspoon of flour in the first box on the foil Test Sheet. Then clean the spoon with a paper towel. (Note: It is very important to clean the spoon between each sample to avoid contamination.) Now place ¼ teaspoon of cream of tartar in the second box and clean the spoon. Continue this process until you have placed samples of each material listed on the Test Sheet, except the clay, in the first row on the foil.
5. Examine the texture of each substance with a magnifying glass and record your result on the Data Table. Is the substance crystalline, granular, powdery, clear?
6. Gather the following materials for making the clay and place them in the small pot:
   1 cup flour
   1 cup salt
   2 teaspoons cream of tartar
   2 tablespoons cooking oil
   ¾ cup water
   DO NOT STIR YET!
7. Observe the materials as you begin to mix them with a spoon (color, texture, etc. Do they dissolve?).
8. Cook and stir the ingredients over medium heat for about 3 minutes or until the clay thickens and does not stick to the pot. Do not overcook.
9. Turn off the heat and remove the pot from the burner. Remove the clay to a table surface and knead it until it is cool. Break off a small piece and place it in the last box of the first line of your foil Test Sheet. Examine its texture and record your results on the first line of your Data Table. Press the clay onto a piece of facial tissue and record your results on the first line of your Data Table.
10. Now place ¼ teaspoon of each material on the second row of the foil Test Sheet. Using an eyedropper, add a small drop of iodine to each of the materials and observe any changes in the color of the iodine. (Iodine is used in this experiment as an indicator for starch.) Record your observations.
11. Place ¼ teaspoon of each material on the third row of the foil. Using the second dropper, add one drop of water to each of these samples. Observe any color changes as you add water to the samples. Record your observations.

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ANALYSIS:

1. Compare the appearance of the combined material used to make the clay with the cooked clay.
2. What materials could you see when you examined the clay with the magnifying glass?
3. What did you discover when you felt the newly made clay and pressed it on the tissue?
4. What did the color changes in the iodine indicate about the substances?
5. Why did you test all ingredients with water?
6. Is clay a mixture or a compound?

OUR FINDINGS:

See Section V.

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FAST AND FIZZY REACTIONS

Rick Broniec

TOPIC:

Chemical Kinetics

INTRODUCTION:

A chemical reaction occurs when two substances, because of their molecular structure, produce a chemical change when they come into contact. Four variables affect the speed of the reaction: concentration, surface area, temperature, and the use of catalysts. This experiment examines two of these: temperature and surface area.

HYPOTHESIS:

Temperature and particle size affect the speed at which a chemical reaction takes place.

TIME NEEDED:

1 hour

MATERIALS:

foil-wrapped Alka Seltzer tablets (10 minimum)
Celsius thermometer
hammer or wood block
3 clear plastic glass tumblers or cups
water
ice cubes
clock or watch with second hand
masking tape or labels

Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

Part A. The Effect of Temperature Changes on the Speed of a Chemical Reaction

1. Label three clean, clear glasses *a*, *b*, and *c* with small pieces of tape or labels.
2. Fill glass *a* half full with ice water. Remove the ice cubes after five minutes.
3. Fill glass *b* half full with room-temperature water (mix hot and cold tap water until the temperature of the mixture is 21° C.
4. Fill glass *c* with hot tap water (38°-48° C).
5. Measure the temperature of the water in each glass. Record the data in Data Table A below.
6. Open three of the Alka Seltzer tablets.
7. Drop one tablet into each glass. Using a clock or watch with a second hand, observe and record the time it takes for each tablet to dissolve completely.

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8. Repeat steps 2-7. This time record the data for each glass under Trial 2.
9. Average the times for Trial 1 and Trial 2 for each glass. Record the averages under the Average Time column.
10. Clean up by pouring the contents of the glasses down the sink.

DATA TABLE A

Glass	Water Temp.	Trial 1 Time	Trial 2 Time	Avg. Time
a				
b				
c				

Part B. The Effect of Particle Size on the Speed of a Chemical Reaction

1. Label two clean, clear glasses *a* and *b*.
2. Fill both glasses half full with cold tap water. Make sure the water in both glasses is at the same temperature.
3. Using a hammer or wood block, crush *one* of the Alka Seltzer tablets *while it is still in the foil packet*. The tablet should be reduced to powder or grains.
4. Open the crushed tablet and a whole tablet.
5. Drop the crushed tablet into glass *a*, stir briefly to mix, and record the amount of time it takes to completely dissolve under Trial 1 in Data Table B.
6. Repeat step 5, but drop the whole tablet in glass *b*. Record the time under Trial 1 in Data Table B.
7. Repeat the experiment and record the data for each glass under Trial 2.
8. Average the times for Trial 1 and Trial 2 for each glass and record under the Average Time column.
9. Clean up by pouring the contents of the glasses down the sink.

DATA TABLE B

Glass	Trial 1 Time	Trial 2 Time	Average Time
a			
b			

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ANALYSIS:

Part A

1. In which glass was the reaction fastest?
2. What explanation can you give for the result in question 1?
3. In which glass was the reaction the slowest? Why?
4. Finish the following statement: The higher the temperature of a reaction, the_____ the reaction will be.

Part B

1. Which reacted faster, the whole or the crushed tablet?
2. What explanation can you give for the result in question 1?
3. Complete the following statement: The_____the size of a reacting particle, the faster the reaction.
4. Explain why explosions might be likely to occur in places where there is a lot of coal dust or sawdust in the air.

OUR FINDINGS:

See Section V.

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NATURAL REACTION BOOSTERS

Dr. C. V. Krishnan

TOPIC:

Catalysts

INTRODUCTION:

The speed of a chemical reaction can be changed by adding a catalyst. Enzymes are catalysts that control chemical reactions in living things. In this experiment you will observe the effect of enzyme catalysts on the decomposition of hydrogen peroxide into water and oxygen.

HYPOTHESIS:

The speed of a chemical reaction is directly related to the strength of the catalyst.

TIME NEEDED:

preparation, ½ hour
to completion, 1 hour for each of 6 trials, ½ hour analysis

MATERIALS:

- baby bottle (with nipple) marked in ounces or milliliters
- 3 pints household hydrogen peroxide (3%)
- metric ruler
- knife
- plastic dishpan
- jar (*e.g.*, jelly jar or pickle jar) with 5 cm mouth
- red potato
- white potato
- turnip
- carrot
- banana
- apple
- water
- balance scale

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Hydrogen peroxide is a common household substance but should still be handled carefully. Wash your hands thoroughly after the experiment or if you spill hydrogen peroxide on them during the procedure. Wash baby bottle thoroughly after use and dispose of it carefully. DO NOT REUSE THE BOTTLE FOR ANY OTHER PURPOSE.

PROCEDURE:

Part A

1. Fill the jar with water.
2. Place the jar in a plastic dishpan.
3. Nearly fill the baby bottle with hydrogen peroxide.

Record the amount of peroxide you are starting with (in ounces or milliliters).

4. Cut a piece of red potato 1 cm long, 1 cm wide, and 1 cm high.

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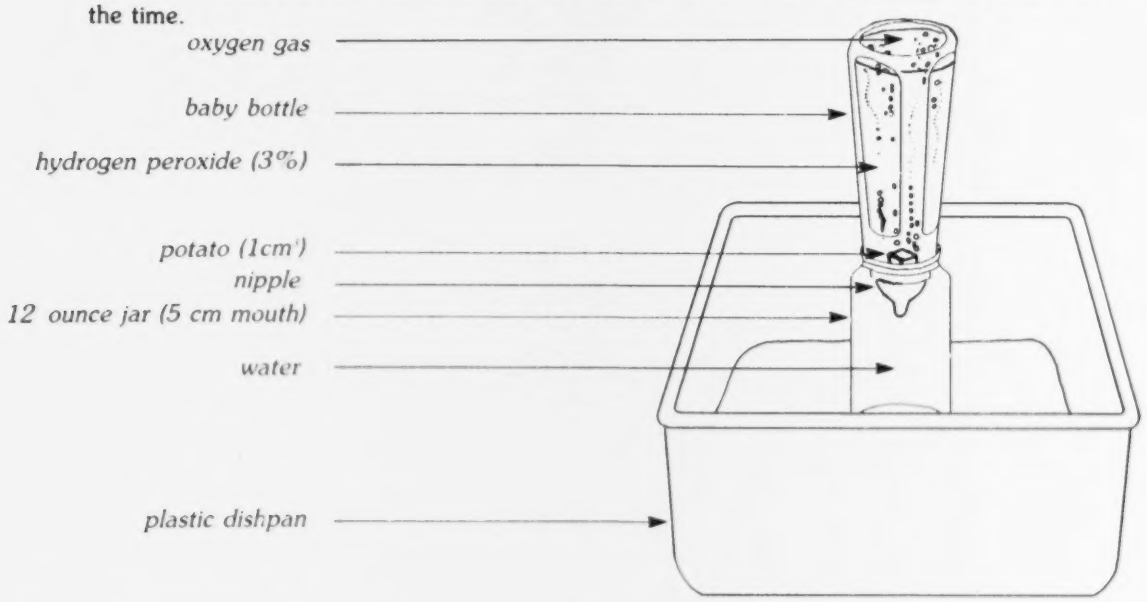
5. Check the nipple of the baby bottle to make sure there is a small hole. Attach the nipple to the bottle cap.

6. Put the cut piece of potato into the baby bottle, immediately close the bottle, and invert into the jar. (See the illustration.) Wash your hands to remove traces of hydrogen peroxide. Note the time.



7. Observe the oxygen bubbles forming inside the baby bottle.

8. At the end of 1 hour, measure the volume of oxygen collected in the baby bottle. To do this, subtract the amount of hydrogen peroxide remaining from the amount you started with. Record this result on the Data Table.

DATA TABLE

Trial No.	ENZYME CATALYST 1 cm³ of	VOLUME OF OXYGEN PRODUCED IN 1 HOUR
1	RED POTATO	
2	WHITE POTATO	
3	TURNIP	
4	CARROT	
5	BANANA	
6	VARIABLE OF YOUR CHOICE (see *Part B*)	

9. Wash the glassware.

10. Repeat the experiment using white potato, turnip, carrot, and banana. Record your results on the Data Table.

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Part B

Do one or more trials of this experiment, choosing from the following variations:

1. Try using a different fruit or vegetable.
2. Try using a potato, carrot, or turnip of the same mass but different surface area than in the original experiment.
3. Try using a vegetable or fruit of different mass than the ones in your experiment.
4. Try using a vegetable or fruit several hours after cutting it.
5. Try using a banana that is more ripe or less ripe than the one in your original experiment.
6. Try using more dilute hydrogen peroxide. (Add 100 ml water to 100 ml hydrogen peroxide.)
7. Try using cooked potato, carrot, or turnip.
8. Try using the same piece of vegetable over again, immediately after its first use.

ANALYSIS:

1. The enzyme catalyst from which vegetable or fruit in *Part A* produced more oxygen in one hour? Which produced the least?
2. Explain which variations you tried in *Part B*. Compare your results with the ones you observed in *Part A*.

OUR FINDINGS:

See Section V.

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PRODUCTS OF COMBUSTION

Virgil Valente

TOPIC:

Combustion

INTRODUCTION:

Combustion (burning) creates heat, light, and flame. It also produces certain chemical substances. In this experiment, you will explore the products of combustion.

HYPOTHESIS:

Combustion produces water and carbon dioxide.

TIME NEEDED:

40 minutes

MATERIALS:

wooden matches
cake pan
several birthday candles (3-4 in. high)
water (or limewater obtained from chemistry lab)
graduated cylinder or large-mouthed clear jar
piece of glass or cardboard large enough to cover mouth of jar
ruler

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. Make sure candle is securely anchored upright before lighting. Use care when lighting candle.

PROCEDURE:

1. Secure the candle to the cake pan with melted wax.
2. Pour water around the candle. Place the jar upside down in the water next to the candle. (See the illustration.) Place the ruler in the water and record the water level.
3. Light the candle carefully.
4. Place the jar over the lit candle. Observe. Record your observations. Put the ruler in the water and note any changes in level.
5. To examine the gas inside the jar, slide a piece of glass or cardboard over the mouth of the jar underwater, trapping the gas and water inside. (This will dislodge the candle, too.) Turn the jar right side up; have someone light a match; and slide the glass or cardboard cover enough to allow the match to be held in the container. Observe. Record your observations.
6. If you are using limewater, reclose the jar and shake to mix the trapped gas with the limewater. Record your observations.

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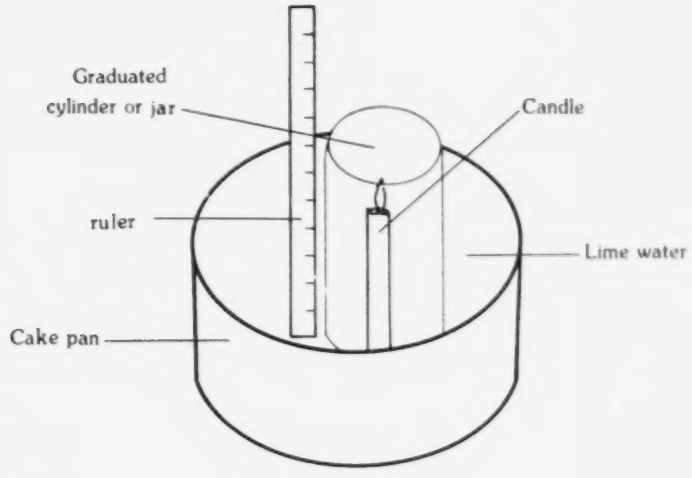

ANALYSIS:

1. What did you see on the sides of the jar after you lit the candle?
2. What happened to the level of water in the pan immediately after you covered the burning candle? What happened to the water level as the candle went out? What explanation can you offer for these changes?
3. If you are using limewater, what other change occurred in the limewater by the end of the experiment? What explanation can you offer for this change?
4. What were the products of combustion you observed in your experiment?
5. Explain what happened to the match in step 5 of the procedure.

OUR FINDINGS:

See Section V.

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WHAT HAPPENS WHEN WATER IS HEATED?

Greg Schell

TOPIC:

Molecular Motion and Convection Currents in Hot Water

INTRODUCTION:

The particles that make up all matter are always in motion, but when heat energy is added they move much faster and bump into each other more often and with greater force. As a result of these collisions, molecules in a heated substance spread farther apart and the substance expands and becomes less dense. In this experiment, you will observe the effects of heating water.

TIME NEEDED:

30 minutes

MATERIALS:

2 identical wide-mouthed jars (20-oz. size)
2 different food colorings in dropper-type bottles
tap water
30 oz. cold water prechilled in refrigerator
index card slightly larger than jar mouth

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Be careful not to burn yourself with hot tapwater. Spillage is possible. Place jars in a sink or on a drainboard.

PROCEDURE:

Part A.

1. Read through this part of the procedure and predict what will happen after step 5. Write down your prediction.
2. Half fill one of the jars with the hottest water the faucet will provide. Use caution so you do not scald yourself.
3. Half fill the other jar with cold water from the refrigerator.
4. Set both jars on a table and wait a minute for the water to settle completely.
5. Take one of each of the food-coloring dropper bottles in each hand and carefully—AT THE SAME TIME—add just a drop of one color to one of the jars of water and a drop of the other color to the other jar.
6. Observe and record what happens.

Part B.

1. Read through this part of the procedure and predict what will happen in steps 7 and 8. Write down your prediction.
2. Completely fill a jar with hot water from the faucet.
3. Completely fill the other jar with cold water from the refrigerator.

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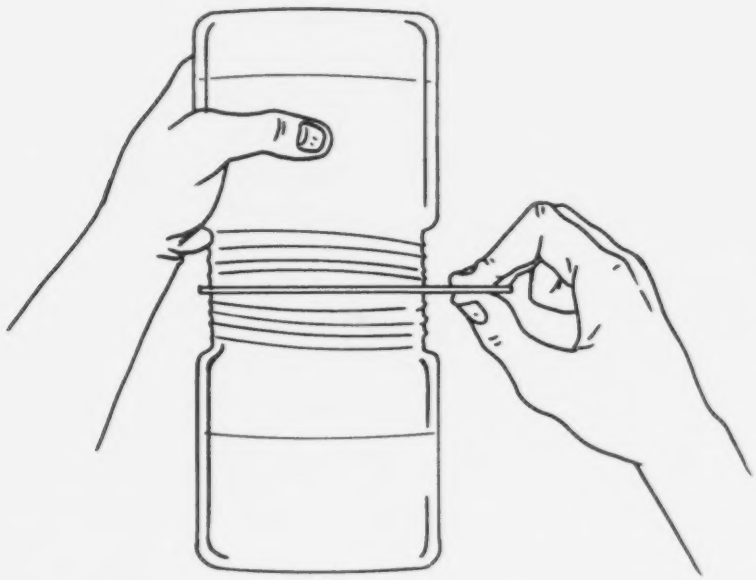
4. Add different colors of food coloring to each.
5. Place the index card over the mouth of the jar filled with hot water.
6. While holding the card in place, quickly invert the jar of hot water and carefully place it on top of the jar filled with cold water as shown in the illustration.



7. While holding the jars in place, carefully remove the card and observe what happens. Is this what you expected?
8. Carefully turn the jars over, so that the hot water is on the bottom. What happens now? Record the results of the last two steps.

ANALYSIS:

1. In *Part A*, did the food coloring disperse in the hot and cold water at the same rate? Did the result match your prediction? If the dispersion rates were different, which was faster?
2. Suggest an explanation for what you observed.
3. What did you observe when you removed the index card in step 7 of *Part B*? Did this result match your prediction of what would happen? Why do you think the water acted the way it did when the cold water was on the bottom?
4. Why do you think the water acted the way it did when the hot water was on the bottom?

OUR FINDINGS:

See Section V.

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HEAT NEEDED TO MELT ICE

Bob Suits

TOPIC:

Heat of Fusion

INTRODUCTION:

The amount of heat necessary to cause one gram of a solid substance to melt into a liquid is called the *heat of fusion* of that substance. Ice works to keep things cold because it absorbs a relatively large quantity of heat before melting. In this lab experiment you will calculate the heat of fusion of ice.

TIME NEEDED:

1 hour

MATERIALS:

ice cubes
water at room temperature
polystyrene cup (8 oz.)
250-ml beaker
source of hot water (use directly from tap or heat on stove or bunsen burner)
100-ml graduated cylinder
Celsius thermometer (−10°-110°)
paper towels
tongs

Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

1. Place several ice cubes in room-temperature water. This step ensures that when you use the ice later in the experiment its temperature will be 0° C, not colder, as it would be coming straight from the freezer.
2. Place 125 ml of water in a beaker and warm it to about 50° C. You may be able to get tap water at this temperature without heating it.
3. Transfer 100 ml of the warm water to the polystyrene cup, using the graduated cylinder.
4. Measure the temperature of the warm water to the nearest 0.1°. Record this figure on the Data Table.
5. Shake excess water from the ice cubes and quickly blot them on a paper towel.
6. Place the ice cubes in the warm water and stir the mixture until the temperature is about 0° C. Do this step as quickly as possible, adding more ice if needed.
7. Measure and record the lowest temperature reached. It does not have to be exactly 0.0°C.
8. Remove any remaining ice with the tongs, shaking dripping water into the polystyrene cup so the total amount of ice melted can be measured.

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DATA TABLE

Temperature of warm water before adding ice cubes	
Temperature of water after melting ice	
Temperature change of water during experiment	
Volume of water in cup after melting ice	
Volume of water in cup before melting ice	
Volume of water from melted ice	

9. Measure and record the volume of water now in the polystyrene cup. From this amount, subtract the volume of water you started with. The result will be the volume added by the melted ice.

ANALYSIS:

Using the data you have obtained, calculate the heat of fusion of ice in calories/g. To calculate the heat (in calories) needed to melt 1 g of ice, you will need two additional pieces of information:

1. The density of water is 1.0 g/ml. Therefore a 15-ml volume of melted ice would be equal to a mass of 15 g of ice.
2. Heat, in calories, is calculated by multiplying the temperature change (°C) in the warm water by the mass (g) of warm water cooled.

Hint: You can calculate the heat (calories) absorbed by the entire mass of ice that melted in the experiment and then divide to find the heat necessary to melt just 1 g of ice (calories/g).

OUR FINDINGS:

See Section V.

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ICE CREAM LAB

Linda Preston

TOPIC:

Lowering Freezing Point

INTRODUCTION:

The *freezing point* is the temperature at which a liquid solidifies. Molecular activity has come to a near standstill when this occurs. You can lower the freezing point of a substance. In this demonstration, you will learn how while making ice cream.

TIME NEEDED:

2 ½ hours (includes time required to chill ice cream mixture before doing experiment)

MATERIALS:

For Each Pair of Students

Celsius thermometer
400-ml beaker, can, or bowl
3-5-oz. paper cup
plastic spoon
stirring rod or stick
crushed ice
rock salt

For Preparation:

wire wisk or electric beater
bowl large enough to hold mixture
gallon milk container
refrigerator

The ingredients listed below will make enough ice cream mixture for 50 pairs of students to do this experiment as directed. You can quarter the mixture or use your own recipe for a smaller number. If you divide this recipe, use only ⅛ tsp. salt.

1 qt. half-and-half
7 cups milk
2 ½ cups sugar
4 eggs
1 tsp. salt
3 tbs. vanilla

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Do NOT use a mercury-filled thermometer.

PROCEDURE:

Part A. Preparation

1. Make up the ice cream mixture using the ingredients above. Beat it until smooth.
2. Store the mixture in a gallon milk container. Chill for at least 2 hours and keep chilled until ready for use.

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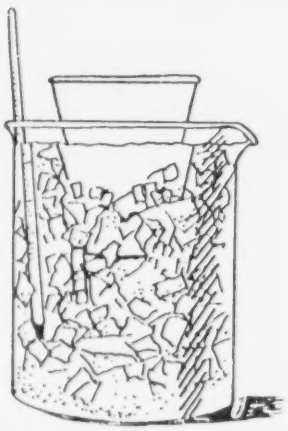
Part B. Making the Ice Cream

1. Find a partner to work with you.
2. Layer crushed ice, some rock salt, and water in the 400-ml beaker. The mixture should be slushy in appearance. The beaker should be filled within 2 cm of its rim.
3. Carefully place the paper cup in the center of the beaker. You may want to double up two cups, one inside the other, to prevent leakage.
4. Fill the paper cup to within 1 cm of its rim with some of the ice cream mixture.
5. With a thermometer, check both the temperature of the ice cream mixture *and* the ice/salt mixture. (See illustration). Record on the Data Table.

measuring the temperature of ice water



DATA TABLE

Time in minutes	Temperature C°	
	ice cream mixture	ice/salt mixture
0		
5		
10		
15		
20		
25		

6. Have your partner stir the ice cream mixture with the plastic spoon while you stir the ice/salt slurry with the stirring rod or stick. Continue to add ice and salt as necessary.
7. Record temperatures every 5 minutes.
8. Continue the experiment until ice cream mixture solidifies.

ANALYSIS:

1. Why was it necessary to stir both mixtures?
2. Describe what you observed happening in the experiment.
3. Why did the ice cream mixture freeze solid when it was sitting in a liquid?
4. How can water be a liquid if the temperature is less than 0° C?

OUR FINDINGS:

See Section V.

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COFFEE AND CREAM SCIENCE

Jim Nelson

TOPIC:

Newton's Law of Cooling

INTRODUCTION:

According to *Newton's law of cooling*, a hot object transfers heat to its surroundings (cools) at a rate proportionate to the difference in temperature between the two. In this experiment you will test this law by answering a practical question: If you are served a cup of coffee that you plan to drink after you have finished eating, and you want the coffee to stay as hot as possible, should you add the cream right away or wait until you are ready to drink it?

TIME NEEDED:

1 hour

MATERIALS:

250-ml beaker (or coffee cup)
50-ml beaker (or a metric measuring cup)
0°-100° Celsius thermometer (or a candy-/deep-fry thermometer and a red-liquid outdoor thermometer)
spoon
graph paper and colored pens or pencils
hot and cold water or coffee and cream
graduated cylinder
watch with second hand

Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

1. Obtain a 250-ml beaker and a 50 ml-beaker to act as a "cup" for the coffee and "pitcher" for the cream or use measuring cups. Fill the beakers to these suggested volumes:

   150 ml of coffee

   40 ml of cream

If coffee and cream are not available, use hot water (about 80° and cold water 10°C).

2. Place a thermometer in the coffee or hot water. Make sure the beaker of hot liquid is not going to spill or be pulled over by the thermometer. (If a laboratory thermometer is not available, you can use a candy/deep-fry thermometer to test the coffee or hot water and an outdoor thermometer to test the cream or cold liquid.) Record your data.

3. When the initial conditions have been noted, start measuring the temperature of the hot liquid every 30 seconds. It is not necessary to repeatedly measure the temperature of the cold liquid. Be sure to note its initial temperature so you can duplicate it in the second trial. Record your data.

4. After making the temperature measurement at 2 minutes, add the cold liquid to the hot liquid and stir. Continue taking temperature readings every 30 seconds for a total of 15 minutes.

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Record them on the Data Table.

DATA TABLE

Starting Temperature, coffee_____ Starting Temperature, cream_____

	Coffee Temperature	
	1st Trial	2nd Trial
30 sec		
1 min		
1 min 30 sec		
2 min		
2 min 30 sec		
3 min		
3 min 30 sec		
4 min		
4 min 30 sec		
5 min		
5 min 30 sec		
6 min		
6 min 30 sec		
7 min		
7 min 30 sec		
8 min		
8 min 30 sec		
9 min		
9 min 30 sec		
10 min		
10 min 30 sec		
11 min		
11 min 30 sec		
12 min		
12 min 30 sec		
13 min		
13 min 30 sec		
14 min		
14 min 30 sec		
15 min		

5. Rinse the beakers or cups.

6. In order to take a second set of data, obtain more hot and cold liquids. To make a valid comparison between trials, the conditions for this second set of data must be *IDENTICAL* to the conditions of the first trial, EXCEPT that the cold liquid should be added after taking the temperature reading at 12 minutes (about the length of a meal). Do not start to take the second set of temperature measurements until the starting temperature of the hot liquid is equal to the starting temperature of the hot liquid on the first trial.

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7. Record the temperature during this second trial every 30 seconds for a total of 15 minutes. Remember to add the cold liquid to the hot liquid after taking the temperture reading at 12 minutes.

8. If you would like to investigate the cooling process further, repeat this experiment, trying one of the following variations: Use two different shaped containers. Use containers made of different materials. Use a different volume ratio of hot to cold liquid.

ANALYSIS:

1. Make a line graph showing the results of both your trials. Put TIME (minutes) on the horizontal axis and TEMPERATURE (Celsius) on the vertical axis. Plot the results of each trial in a different color.

2. Which cup of liquid was hotter after 15 minutes? What conclusion can you draw from this result?

3. If you tried one of the variations in step 8, describe any variations in the results. Explain these new results.

OUR FINDINGS:

See Section V.

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THE BOLTZMANN DISTRIBUTION

Lee Marek

TOPIC:

Distribution of Kinetic Energy

INTRODUCTION:

Temperature is the average kinetic energy of the particles that make up a substance. *Kinetic energy* is the energy a particle has because of its mass and the speed at which it zips around in space. In any substance, some particles have more kinetic energy than the average; some have less. If you could stack up all the particles whizzing about with the same kinetic energy, and compare all the different stacks, you would be examining the distribution of kinetic energy in a substance. The distribution of kinetic energy in a substance is known as the *Boltzmann distribution*. In this demonstration you will discover the shape of the curve of a Boltzmann distribution.

TIME NEEDED:

30 minutes

MATERIALS:

For School:
200 kernels of popcorn
1,000- or 1,500-ml tall form beaker
25–30 ml cooking oil
burner
ring stand
metal screen
aluminum foil
stopwatch or a clock with second hand
graph paper
felt tip pen

For Home:
400 kernels popping corn (50 ml)
3-liter pot at least 10 cm high (glass works best) with a tight-fitting lid
15 ml cooking oil
stove or electric burner
stopwatch or a clock with a second hand
graph paper
felt tip pen

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Remember to wear safety goggles.

PROCEDURE:

For School

1. Choose a partner for this experiment.
2. Divide an 8½ x 11 plain sheet of paper into boxes for a timing grid as shown in the illustration.

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0-15 sec.	16-30 sec.	31-45 sec.	46-60 sec.
1-1:15	1:16-1:30		

each box represents 15 seconds

3. Pour 25-30 ml of oil into the beaker. Use new beakers and save them for this lab alone to avoid contamination.
4. Cover the metal screen with three pieces of aluminum foil to spread out the heat on the beaker bottom.
5. Place the beaker on the screen and make sure it is level and the burner centered under it. Heat the beaker.
6. Put one kernel of popcorn in the hottest part of the oil. When it pops, add the rest. Cover the beaker with a piece of aluminum foil with a small hole in the center and secure the foil.
7. Start timing when the next kernel pops. Record the number of pops that occur in 15-second intervals. One person should call out the time intervals while the other puts dots in the timing grid for each pop. Since the kernels pop fast, you may have to estimate the pops for some time periods.

For Home

1. Using a plain sheet of paper, divide it into a timing grid as shown above.
2. Place oil and popping corn in the cooking pot, cover, and cook over medium heat.
3. Listen carefully. Start timing when you hear the first pop. Have a friend begin counting 15-second intervals. Begin with the first square, record the number of pops that occur in 15 seconds by placing a dot in the box for each pop heard. At the end of 15 seconds, move to square two and repeat the procedure. (When corn is popping quickly, each pop is hard to hear, so you will have to estimate.)

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ANALYSIS:

1. Count the number of dots in each box and graph the results. Draw as smooth a curve as you can showing the point distribution. The graph is a plot of the number of pops in an interval as a function of time. For better data, repeat the whole procedure a few times, make all the g aphs and then make a graph of the average number of pops in each box of the same number.
2. Relate the graph shape to a Boltzmann distribution.
3. Where does the analogy break down? Hint: What would the popcorn curve look like if the popcorn were heated in a hotter flame (higher temperature)?
4. What causes the popcorn to pop?
5. Why didn't all the kernels pop at once?

OUR FINDINGS:

See Section V.

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BUBBLE FILMS AND BOAT RACES

Kathleen Scullen

TOPIC:

Surface Tension and Cohesion

INTRODUCTION:

Surface tension is a force observed in the boundary surface, the top or exposed surface, of a liquid. Because of the cohesion of liquid molecules, the surface behaves as if it were an elastic film stretched over the liquid and pulls itself into the smallest area possible. In this activity, you will observe this and see how other factors influence surface tension.

TIME NEEDED:

1 hour

MATERIALS:

measuring cup
dishpan or sink
water
½ cup liquid dish detergent
½ cup corn syrup or granulated sugar
clay
toothpicks
glue
needle and thread
yarn
twist ties or pipe cleaners
straws
clock or watch
wax paper
newspaper page
large-mouthed bottle
refrigerator or other cold source
lamp, oven, or other heat source
different-sized juice, soup, or other grocery cans with both ends removed
12-ft. string
scissors
paper clips
plastic fork
bar of soap
optional:
hula hoop
small wading pool

Safety Precautions

Adult supervision required for parts of this experiment. Please read and copy the safety precautions at the beginning of this book. Do not blow through jagged edges of cans.

PROCEDURE:

Part A. Bubble Films

First, prepare bubble solution in a clean dishpan or sink by mixing:

10 cups water
½ cup liquid dish detergent
½ cup corn syrup (Granulated sugar may be substituted, if stirred well.)

Make sure the solution has no surface bubbles before proceeding.

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Use the bubble solution to try the following experiments:

1. Explore the cohesion of like water molecules in the soap solution by creating different shapes using household materials that are dipped into the solution.
   a) Use small balls of clay as joints to hold toothpicks together in two- or three-dimensional shapes. Dipping the toothpicks in glue beforehand provides stability.
   b) Use either a threaded needle, yarn, or twist ties to fasten cut straw pieces into dimensional shapes, as shown in figure 1.

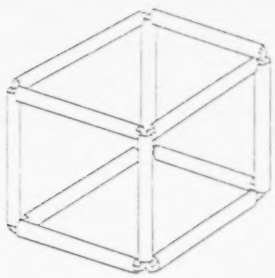

figure 1

Predict how many bubble film sides (faces) will form after the shapes are dipped into the solution, then fill out Data Table 1 with the actual number.

DATA TABLE 1

Drawing of shape				
Predicted faces				
Actual counted faces				
Difference				

2. Explore how different surfaces affect bubble life.
   a) Make a bubble holder by inserting a twist tie or pipe cleaner into a straw, as as shown below in figure 2.

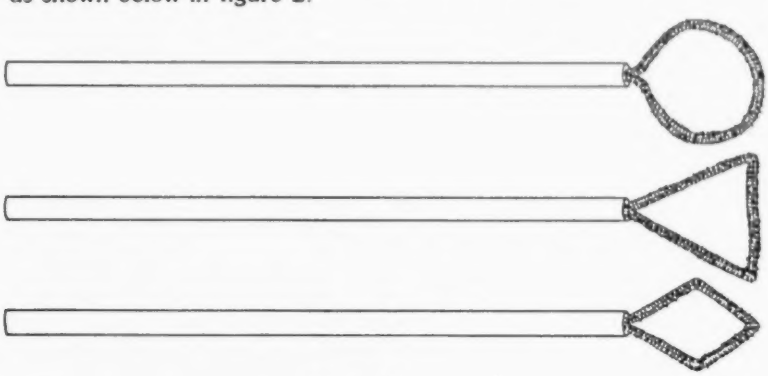

figure 2

   b) Dip the holder into the solution, then blow or swing it to form a bubble. Catch the bubble in the holder. Time its life in open air.
   c) Repeat the above, but change the bubble location to: a dry table, a wet table

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area, the edge of a table, a piece of wax paper, a piece of newspaper. Record times for each surface on the Data Table 2.

DATA TABLE 2

	Different surfaces	Time of bubble life in seconds
1.	Open air on a holder	
2.	On a dry table	
3.	On a wet table	
4.	On wax paper	
5.	On newspaper	
6.	At the edge of a table	

3. Explore how environmental humidity and temperature affect bubble life:
   a) Time bubbles put under a moistened inverted bottle on wet and dry surfaces.
   b) Time bubbles placed near a cold source and near a heat source. (ADULT SUPERVISION NEEDED). Record times on Data Table 3.

DATA TABLE 3

	Humidity or temperature	Time of bubble life in seconds
1.	Under moist inverted bottle on wet surface	
2.	Under inverted bottle on dry surface	
3.	Open air near cold source	
4.	Open air near heat source	

4. Compare bubble shapes and sizes from different holders:
   a) Using different-sized cans with both ends removed, swing bubbles out, as shown in figure 3. Compare their sizes.

figure 3

b) Make soap frames from straws and string. Blow or swing frames. Also lower

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or cross frames with each other to create lattices.

c) Optional: To make bubbles outdoors use hula hoops in small wading pools with soap solution. Does a bubble change shape when blown from different sources?

5. Blow a bubble using the holders made in step 2. Catch the bubble on the holder. Moisten a tip of a straw and insert it into the bubble. Exhale gently to blow a small bubble inside the large one.

Part B. Boat Races

1. Fill a clean dishpan to the brim with water and then carefully add more water until the surface rises above the rim, forming a bubble-dome shape.
2. Set a paper clip on a plastic fork and slowly lower it into the water until the clip floats on the surface, as shown in figure 4.

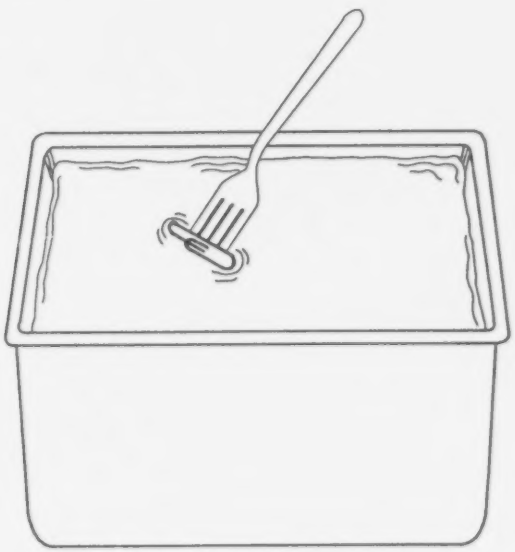

figure 4

3. Place a soap bar in the water behind the clip to power it around the dishpan until the clip sinks. Race paper clip boats to see which stays afloat longest or travels farthest.

ANALYSIS:

1. In Data Table 1, explain any differences between the number of faces you predicted the bubbles would have and the actual numbers.
2. In Data Table 2, which surfaces extended the life of the bubbles? Can you explain why?
3. In Data Table 3, explain the effects of changes in temperature and humidity on the bubbles.
4. In step 4, what effect did changing the size and shape of the source have on the size and shape of the bubble?
5. In step 5, were you able to blow a bubble into an existing bubble? Explain why this was or was not possible.
6. In *Part B*, what allowed the paper clip boat to stay afloat? Explain the effect of the bar of soap.

OUR FINDINGS:

See Section V.

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METAL FLOATS

Warren B. Van Camp

TOPIC:

Density and Displacement

INTRODUCTION:

Although metal objects generally do not float in water, metal boats do. In this experiment you will find out why by studying the related factors of weight, volume, and density in floating objects.

TIME NEEDED:

1 hour

MATERIALS:

- sheet of soft metal (e.g., copper, brass, tin; do not use aluminum) about 3 in. square
- soldering gun and solder
- piece of wood about the same weight as the metal
- balance scale
- plastic gallon jug
- scissors or X-acto knife
- water
- metal shots, such as copper or iron, for ballast
- grease pencil
- large spoon or turkey baster
- a small cup or beaker

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. Have an adult solder the metal.

PROCEDURE:

Part A

1. Have an adult fold the sheet of metal in half and solder shut the far ends. Do no solder shut the side opposite the fold.
2. Weigh the soldered piece of metal and the block of wood to see that they weigh about the same.
3. Cut the gallon jug in half horizontally with the scissors or X-acto knife and fill two-thirds full of water.
4. Place the block of wood in the jug of water.
5. Record what you observe. (Does the wood float or sink?)
6. Place the piece of metal in the jug of water. Record what you observe. (Does the metal float or sink?)
7. Take the piece of metal out of the water. Grasp the unfastened edge and pull the two sides apart so that they are open about one inch, forming a little boat, as shown in the following illustration.

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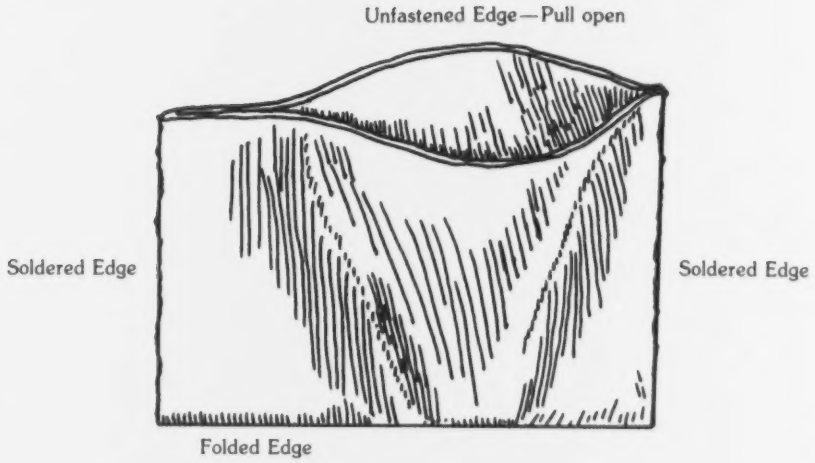

8. Place the opened piece of metal in the jug of water. Record what you observe. (Does the opened piece of metal float or sink?)

Part B

1. Float the opened boat in the water and carefully pour metal shot into it to determine the maximum amount it can take without sinking.
2. Remove the loaded boat and weigh it on the balance scale. Record the weight.
3. With the boat still out of the water, carefully mark the water level on the outside of the jug with the grease pencil.
4. Place the loaded boat back into the water and mark off the new water level with the grease pencil.
5. Weigh a small cup and record its weight.
6. Using a spoon or a turkey baster, transfer the displaced water (all the water above the original water level line) into the cup that you weighed. Measure the weight of the displaced water by subtracting the weight of the cup from the total weight of the cup and water. Record this weight.
7. Remove the loaded boat from the water; take out half of the metal shot; and repeat steps 2-6.

ANALYSIS:

Part A

1. Compare what happened to the wood with what happened to the closed piece of metal. Explain why you think the results were different.
2. What happened when you opened the metal into a little boat? Explain why.

Part B

1. Compare the weight of the displaced water with that of the loaded boat in both trials. What do you find?
2. If the boat were twice as big but made of a substance that was three times as light, would it displace more or less water?

OUR FINDINGS:

See Section V.

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THE SPECTACULAR SIPHON

Courtney W. Willis

TOPIC:

Properties of Fluids

INTRODUCTION:

A siphon is a tube used to transfer liquids from one container to another. Siphons have been known since ancient times; however, exactly how a siphon works and what legitimately can be called a siphon are still under debate among scientists today. In this experiment you will look at simple and intermittent siphons in action. Intermittent siphons are the mechanism by which toilets flush. Some scientists believe that a common siphon works mostly by air pressure working against gravity. Others believe it works because of a combination of gravity and the cohesive forces of fluid molecules. This experiment will also demonstrate a siphon that works without a tube to transmit the liquid.

HYPOTHESIS:

The operation of a siphon depends on the level of water at two different places.

TIME NEEDED:

Parts A and B, 1 hour; *Part C*, 1 day

MATERIALS:

2 2-liter plastic soda bottles
knife
water
2 pieces of flexible clear plastic tubing (25 cm and 40 cm long) to fit hole in stopper
1-hole # 4 rubber stopper to fit spout of bottle
small block of wood or book
about 20 cm of toilet tissue
glycerin or petroleum jelly

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Care should be taken with the knife when cutting the plastic bottles in half.

PROCEDURE:

Part A. Observing a Simple Siphon

1. Carefully cut the plastic bottles in half. Set the two top halves aside. They will be used in a later part of the experiment.
2. Fill one of the bottom halves three-fourths full of water, then set on a table top next to the empty second bottom half.
3. Submerge the longer piece of plastic tubing into the water in the filled bottom half and let it fill with water. Put your finger over one end of the tubing, so that water cannot enter or leave.

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Then bring that end of the tubing out of the water and place it into the bottom of the other container so that half of the tubing is in each container.

4. Remove your finger from the tubing and observe what happens. Record your observations of the water level in each side of the tube.

5. Raise one of the containers off the table top a couple of inches by slipping a block or book underneath it. What happens this time? Record your observations.

6. Try raising the second container and putting the first back on the table. When the water stops flowing, record your observations of the water levels in each side of the tube.

7. Some people believe that it is the different weights of water on each side of the tube that make the water flow. To see if this is true, try putting all the water back into one container. Fill the tubing with water. Put your finger over the end and lift the tubing out of the filled container and into the empty container. Make sure that most of the tubing remains in the original container so that that side has the most water in it. (See figure 1.) Remove your finger from the tubing. What happens?

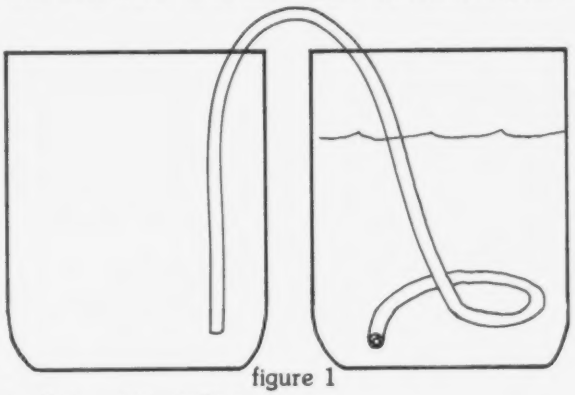

figure 1

Part B. Observing an Intermittent Siphon

1. Insert the long piece of tubing into the rubber stopper by first gently lubricating it with some glycerin or petroleum jelly.

2. Insert the stopper and the tubing into one of the top halves of the bottles that were put aside earlier. The tubing should be inserted in the bottle's spout.

3. Turn the bottle upside down so that the tubing is now coming out of the bottom. Loop the tubing back up so that it comes about halfway up the bottle and then down below the bottom again as shown in figure 2. Position the end of the tubing over a sink drain.

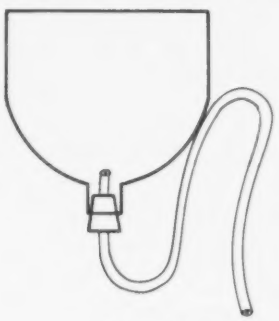

figure 2

4. Slowly begin to fill the container with water. Does anything seem to happen at first? Keep adding water. When does the water start to flow? When the water stops flowing, how much is left in the container?

5. Another ancient intermittent siphon is called a Tantalus Cup. A simple example can be constructed by pushing the short piece of plastic tubing through the narrow end of the stopper, then inserting the tube and stopper into one of the top halves of the plastic bottles. Turn upside down and loop the free end of the tubing back down toward the bottom as shown in figure 3. Slowly fill the "cup" with water. When does the water start to flow out the bottom?

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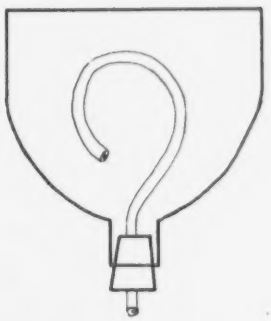

figure 3

Part C. A Siphon Without a Tube

1. Set the 2 bottom halves of the soda bottles next to each other with one of them filled and one of them empty.
2. Roll the toilet tissue lengthwise into a loose roll about 20 cm long as shown in figure 4.

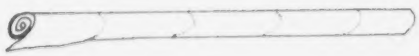

figure 4

3. Put the toilet tissue into both containers so that half hangs in the filled container and half hangs in the empty container (figure 5). Observe the water start to climb up the tissue due to capillary action. Let everything sit overnight. What happens? Record your observations.

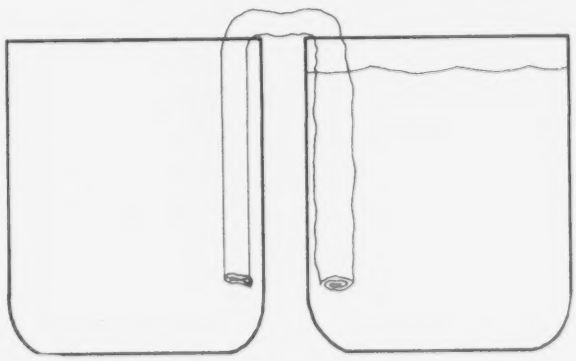

figure 5

ANALYSIS:

Part A

1. What did you observe when you removed your finger from the tube in step 4? How did the final water levels in each side of the tube compare?
2. Did changing the relative positions of the containers in step 5 change the relative water levels in each side of the tube? Explain.
3. Did changing the length of tubing on each side affect the action of the siphon? Explain. What conclusion can you draw from this result?

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Part B

1. What happened when a small amount of water was placed in the first intermittent siphon? What happened when a larger amount of water was placed in it?
2. Can you think of an intermittent siphon in your home that operates on the same principle? Explain.
3. Explain what happened with the Tantalus Cup. Research Tantalus in Greek mythology and explain how the siphon got its name.

Part C

1. What happened in the tubeless siphon overnight?
2. In what way is the functioning of this apparatus similar to an ordinary siphon? In what way is it different?
3. What general conclusion can you make about how siphons operate?

OUR FINDINGS:

See Section V.

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BOILING AND FREEZING A BALLOON

Annabelle L. Lerch

TOPIC:

Charles' Law

INTRODUCTION:

The volumes of different liquids and solids will vary according to the size and nature of their specific molecules. In a gas the molecules are relatively far apart, and thus general laws can be stated about how environmental conditions affect gas volume. In this experiment you will explore the relationship between temperature and volume of a gas.

HYPOTHESIS:

At constant pressure, gas volume is directly related to temperature.

TIME NEEDED:

20 minutes

MATERIALS:

2 1-liter beakers or pots
stove, hot plate, or bunsen burner
ice
salt
Celsius thermometer
round, medium-sized balloon
string
metric ruler
felt-tip pen
tongs
clock or watch

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. Use tongs to lower the balloon into the boiling water and to hold it there.

PROCEDURE:

You will need a partner for this procedure.

1. Prepare your hot and cold water baths. Fill one of the pots or beakers ⅔ full of water, place on stove or hotplate (for pot) or over bunsen burner (for beaker), and heat until simmering. Fill the other beaker or pot ⅔ full with a mixture of cold water and ice in equal proportions. Add salt to the ice water to lower the freezing point until the temperature is below 0° C and bring the hot water to a boil.
2. Blow up the balloon and tie securely. Make sure that the balloon will fit into your beakers or pots.
3. With string and metric ruler, measure the circumference of the balloon (the distance around

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it) and trace the circumference with your pen. Then calculate the volume in centimeters using the formulas:

$$r = c/2\pi \text{ and } v = 4/3\pi r^3$$

where
r = radius
c = circumference
v = volume
$\pi = 3.14$

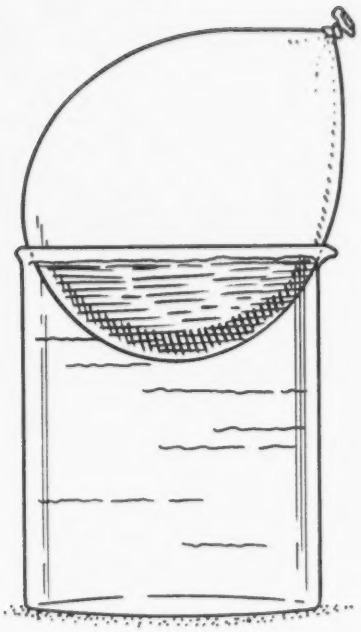

figure 1

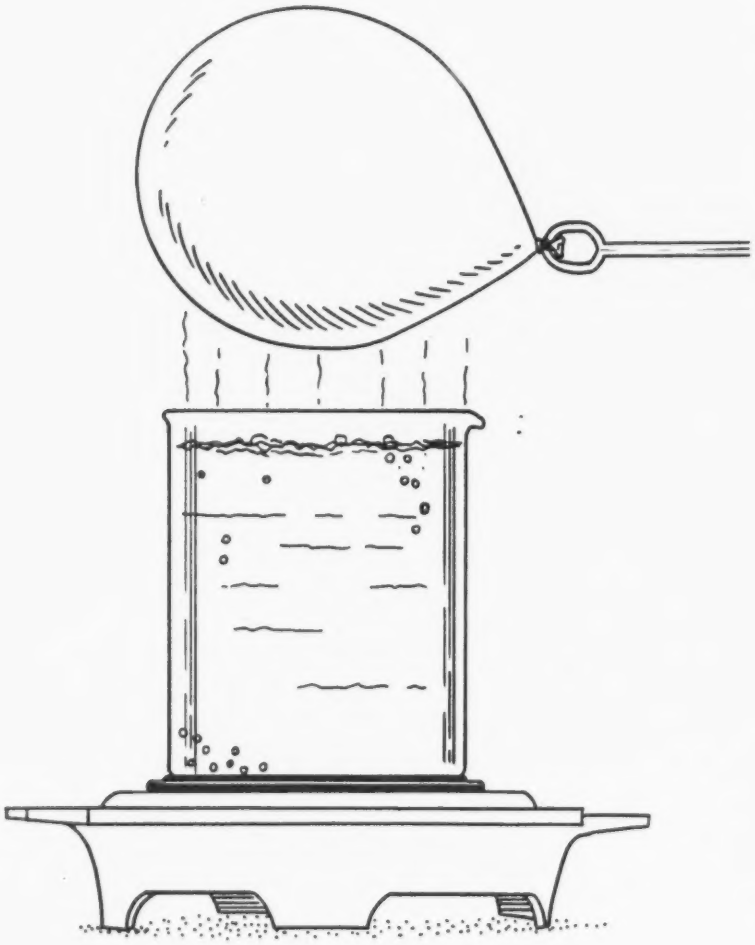

figure 2

Record the volume, then check the air temperature in the room and record it next to the volume.

4. Note the time and place the balloon in the ice water bath until you can see a change in the size, about 2-3 minutes. Note the time elapsed since you put the balloon in water. Record the temperature of the water. Then quickly determine the circumference of the balloon, using the string and metric ruler. Calculate the volume of air inside the balloon now and record this figure next to the temperature of the water.

5. Now, using tongs, hold the balloon over the boiling water. Again, note the time. Hold the balloon in the steam for the same amount of time it was immersed in cold water and then carefully measure its circumference. This will require two persons, one to continue holding the balloon with tongs and one to measure. Be particularly careful when measuring the circumference in the steam. Calculate the volume of air in the balloon. Record your data along with the tempera ture of steam.

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ANALYSIS:

Make a line graph of your results, with temperature in °C on the horizontal axis and volume in cm^3 on the vertical axis. Describe the relationship between temperature and volume of a gas indicated by your data. Draw a straight line through the points and extend it to determine the temperature at which the volume of an ideal gas equals zero.

OUR FINDINGS:

See Section V.

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GASES HAVE THEIR UPS AND DOWNS

Carol B. Collins

TOPIC:

Boyle's Law

INTRODUCTION:

In the seventeenth century, the Anglo-Irish chemist Robert Boyle, called the father of modern chemistry, showed that the volume of a gas varies inversely with its pressure, provided the temperature does not change. That is, as the pressure of the gas increases, its volume decreases; as the pressure decreases, the volume increases. The law can be seen easily in such piston-type compressors as the bicycle pump. In this experiment you will attempt to prove Boyle's Law.

HYPOTHESIS:

The pressure and volume of a gas are inversely proportional, assuming a constant temperature.

TIME NEEDED:

30 minutes

MATERIALS:

1-liter graduated cylinder or hydrometer jar (preferably plastic)
gas measuring tube (eudiometer)
metric ruler
Celsius thermometer (preferably red-liquid filled)
barometer (or information from the weather bureau)

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

Part A

1. Nearly fill the graduated cylinder with water.
2. Half fill the gas measuring tube with water.
3. Place your thumb over the mouth of the gas measuring tube to trap air inside the tube and quickly invert the tube into the cylinder.
4. Hold the gas measuring tube so that the water levels inside the tube and in the graduated cylinder are *equal*—so the two water levels match up. (See figure 1.)

Read the volume of the air trapped in the gas measuring tube. If you are using a plastic cylinder that is somewhat opaque, you may have to place a lamp behind it and hold the gas tube close

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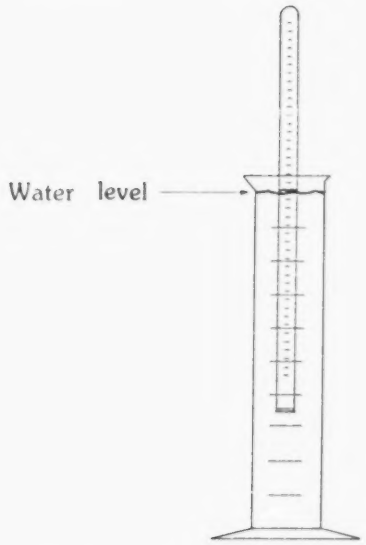

figure 1

to the side you are looking through in order to read the levels accurately. A little adjustment should make this possible even if the cylinder is quite opaque. Record the figure on the Data Table in the Analysis section.

5. Measure and record the temperature of the water in the graduated cylinder.

6. Record the barometric pressure. If you do not have a barometer, you can get the barometric pressure from your local weather bureau. They may give this information in inches of mercury in which case you can convert it to millimeters of mercury (mm Hg).

To convert a value in inches to mm Hg, multiply the number of inches by 25.4.

Part B

1. Without removing the gas measuring tube from the cylinder, lift the tube so that the water level in the tube is *higher* than the water level in the graduated cylinder. (See figure 2.)

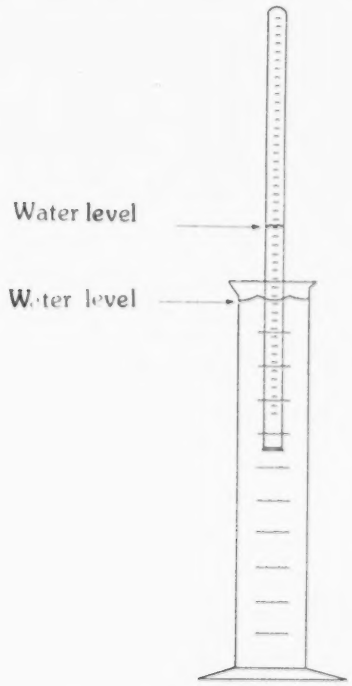

figure 2

How much you lift the tube is not important as long as you do not pull the end all the way out of the water in the cylinder.

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2. Holding the gas measuring tube firmly in place, measure the difference in water heights with a ruler, making sure that the ruler does not become submerged in the water. Record.
3. Still holding the gas measuring tube in place, measure the new volume of air in the tube and record.
4. Measure and record the temperature of the water.
5. Now move the gas measuring tube to a different height and repeat steps 1-4.

Part C

1. Repeat *Part B*, except this time lower the gas measuring tube into the cylinder so that the water level inside the gas measuring tube is *lower* than the water level in the graduated cylinder. (See figure 3.)

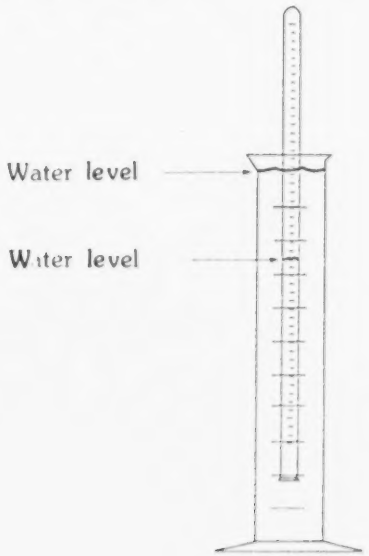

figure 3

2. Measure the water height difference and the air volume inside the tube.
3. Move the gas measuring tube even lower into the graduated cylinder and repeat the measurements.

ANALYSIS:

When the levels of water in the tube and the cylinder are equal, the pressure of the gas in the tube and the air outside are equal (both maintain the water column level at the same height). Thus the pressure in the tube = atmospheric pressure (barometer reading) after correcting for water-vapor pressure (explained below). In parts B and C of the procedure, you changed this pressure inside the tube by raising and lowering the tube inside the cylinder. When the water level inside the tube is *higher* than in the cylinder, the pressure of the air inside the tube is equal to atmospheric pressure *minus* the difference in the height of the two water levels. When the water level in the tube is *lower* than in the cylinder, the pressure of the air inside the tube equals atmospheric pressure *plus* the difference in height.

In order to make an accurate calculation of pressure × volume, in addition to taking the measurements with the tube and the cylinder, you must make the correction and conversions explained below and provided for on the Data Table.

Correcting for water vapor pressure

Because you are trapping air above water, some of the water vaporizes and adds to the pressure in the tube. To correct for this, look at the Water Vapor Pressure Table for the pressure corresponding to water temperature in each part. Enter these values on line 4 of the Data Table. Later you will subtract this value to make the correction.

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DATA TABLE

Part A

1. Volume of gas in tube ..... _____ ml
2. Barometric (atmospheric) pressure ..... _____ mm Hg
   (Use a barometer to measure or call weather bureau)
3. Temperature of water ..... _____ °C.
4. Water vapor pressure at _____ °C ..... _____ mm Hg
5. Pressure of dry air in tube [(2) − (4)] ..... _____ mm Hg
6. P × V = (5)/760 × (1)/1000 ..... _____ L • atm

Part B

	Trial 1	Trial 2
1. Volume of gas in tube	_____ ml	_____ ml
2. Barometric (atmospheric) pressure	_____ mm Hg	_____ mm Hg
3. Temperature of water	_____ °C	_____ °C
4. Water vapor pressure at _____ °C	_____ mm Hg	_____ mm Hg
5. Difference in water heights	_____ mm H_2O	_____ mm H_2O
6. Equivalent height in Hg (5)/13.6	_____ mm Hg	_____ mm Hg
7. Pressure of dry air in tube [(2) − (4) − (6)]	_____ mm Hg	_____ mm Hg
8. P × V = (7)/760 × (1)/1000	_____ L • atm	_____ L • atm

Part C

	Trial 1	Trial 2
1. Volume of gas in tube	_____ ml	_____ ml
2. Barometric (atmospheric) pressure	_____ mm Hg	_____ mm Hg
3. Temperature of water	_____ °C	_____ °C
4. Water vapor pressure at _____ °C	_____ mm Hg	_____ mm Hg
5. Difference in water heights	_____ mm H_2O	_____ mm H_2O
6. Equivalent height in Hg (5)/13.6	_____ mm Hg	_____ mm Hg
7. Pressure of dry air in tube [(2) − (4) + (6)]	_____ mm Hg	_____ mm Hg
8. P × V = (7)/760 × (1)/1000	_____ L • atm	_____ L • atm

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Water Vapor Pressure Table

°C	mm	°C	mm	°C	mm	°C	mm
0.0	4.6	17.0	14.5	21.0	18.7	25.0	23.8
5.0	6.5	18.0	15.5	22.0	19.8	26.0	25.2
10.0	9.2	19.0	16.5	23.0	21.1	27.0	26.7
15.0	12.8	20.0	17.5	24.0	22.4	28.0	28.3

Converting pressure and volume units

The Boyle's Law constant is usually written in "atmospheres × liters" (L • atm). 1 atm = 760 mm Hg (the pressure exerted by a column of mercury 760 mm high). We have already discussed converting a barometer reading to mm Hg. Since you are working with a column of water in this procedure, whenever you measure water height, you will need to convert this to mm Hg—that is, the height of a column of mercury that would exert the same pressure as that column of water. You can do this by dividing the water height (in mm) by the density of mercury compared with water, which is a factor of 13.6. This is the purpose of step 6 in parts *B* and *C* of the Data Table. In the last step of each part, the values of P and V are converted from mm Hg to atm and from ml (milliliters) to L (liters). Since 760 mm Hg = 1 atm, the value of P is divided by 760 to put it in units of atm. Because there are 1000 milliliters in a liter, the measurement of V is divided by 1000. The final product of P × V is then expressed in the conventional unit, L • atm

OUR FINDINGS:

See Section V.

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WATCHING ATMOSPHERIC PRESSURE AT WORK

Michael Minnema and Lois Fruen

TOPIC:

Gas Pressure and Work

INTRODUCTION:

Pressure equals the amount of force per unit area on a surface. When you blow into a balloon, the air from your breath increases the number of air molecules in the balloon causing the balloon to expand. There is also an atmospheric pressure (the pressure of the moving molecules of air) on the outside walls of the balloon caused by air molecules in the room bouncing off the balloon. To get the balloon to expand, you must blow enough air into the balloon to counteract atmospheric pressure. This experiment sets up conditions in which you can observe a dramatic effect of atmospheric pressure and calculate the work it does during the event.

TIME NEEDED:

40 minutes

MATERIALS:

soda can
water
100-ml graduated cylinder
400-ml graduated cylinder
stove or hot plate
beaker tongs
large container of water
barometer (or information from your local weather bureau)

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. Use extreme caution when heating can because steam can cause serious burns. Handle can with tongs. Step back after inverting hot can in water.

PROCEDURE:

1. Fill a soda can with water until it is just about to overflow. Then pour the water into the large graduated cylinder. Record the water volume here._____ This is the volume of the can before heating.
2. Now measure 30 ml of water in the small graduated cylinder. Pour the water into the can and, using tongs to hold the can, heat until the water boils vigorously. Do not boil to dryness.
3. Quickly invert the can into the large container of water. Step back and observe the results.
4. Remove the can and fill it with water. Pour the water into the graduated cylinder to measure the final volume. Record the volume here._____ This is the volume of the can after heating.
5. From the barometer, determine the atmospheric pressure at the location where the experiment was performed.

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ANALYSIS:

1. Subtract the final volume of the can from its original volume. Record the change in volume in ml here._____

2. Now use the change in volume to calculate the work done by atmospheric pressure. To do this you will need a formula relating work and pressure.

The formula for work is:

$w = fd$ where w = work
f = force
d = distance.

Atmospheric pressure is defined as the force exerted by the atmosphere on the surface of a body per unit of area. Thus,

$p = f/d^2$ where p = atmospheric pressure
f = force
d^2 = distance squared = area.

We can combine these two equations to find the relationship between pressure and work. Express the pressure equation in terms of force by multiplying both sides by d^2:

$$pd^2 = f/\!\!\not{d}^2(d^2) = f.$$

Now, substitute this new definition of force,

$$f = pd^2,$$

into the equation for work:

$$w = pd^2d.$$

Simplify:

$w = pd^3$ where d^3 = distance^3 = volume
$w = pv$ where v = volume.

To apply this equation to the procedure you just performed, take the barometer reading as p, and the *difference* between the initial volume of the can and the volume after its collapse as v. Solve for w, the work done by atmospheric pressure.

To obtain an answer in standard units of work, you will need to make the following conversions. Pressure should be given in mmHg (millimeters of mercury). If your barometer or weather bureau gives you pressure in inches of mercury, you can convert it to mmHg by multiplying by 25.4 (the number of millimeters per inch). A standard unit of work is the joule (1 joule = 7501 ml × mmHg). After you have multiplied your pressure and volume measurements, divide your answer by 7501 to convert your answer into joules.

3. Write an explanation of what happened during the procedure. What role did the water in the can play? Did the air pressure inside the can remain the same throughout? If not, when did it change? What role did the air pressure play in what you observed?

4. What other examples can you think of in which atmospheric pressure does work?

OUR FINDINGS:

See Section V.

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SOME SALTS CAN BE NEUTRALIZERS

Mary Alice Kubovy

TOPIC:

Hydrolysis

INTRODUCTION:

Salts can be either acidic, basic or neutral in solution. An acidic solution is one containing more H^+ ions than pure water; a basic solution is one containing more OH^- ions than pure water. Neutral solutions are neither acidic nor basic because they contain an equal amount of H_3O^{+1} and OH^{-1} ions. Scientists use a scale of value 1-14 known as pH to define hydrogen ion concentration. For neutral solutions pH = 7, for basic solutions pH>7, and for acid solutions pH<7. You can test whether a solution is acidic, basic, or neutral by using a substance called an indicator. In this demonstration you will use grape juice to analyze some common household substances that are salts.

TIME NEEDED:

30 minutes

MATERIALS:

grape juice
baking soda (sodium bicarbonate)
alum
washing soda (Arm & Hammer brand works well)
antacid tablet (Tums or Rolaids brands, for example)
table salt
epsom salts
soap flakes (Ivory Flakes brand works well)
cream of tartar
vinegar
ammonia cleaning solution
distilled water
10 clear plastic cups
plastic measuring spoons

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Do not taste any of these substances. After the experiment, dispose of solutions by washing them down the drain. Use plenty of water.

PROCEDURE:

1. Use grape juice as the acid-base indicator. First, put several drops of grape juice in ½ cup of vinegar to determine the color of grape juice in an acid. Stir and note the color here._____

2. Now put several drops of grape juice in ½ cup of ammonia cleaning solution to determine the color of grape juice in a base. Stir and note the color here_____.

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3. Dissolve ¼ tsp. of each salt in individual ½ cups of distilled water. Stir to dissolve each solution.
4. Add several drops of grape juice to each solution and note the color.
5. Fill in the Data Table.
6. Carefully dispose of all solutions.

DATA TABLE

Salt	Common Name	Color of Solution + Grape Juice	Type of Solution: Acid, Base, or Neutral?
$NaHCO_3$	Baking Soda		
$KAl(SO_4)_2 \cdot 12H_2O$	Alum		
$Na_2CO_3 \cdot 10H_2O$	Washing Soda		
$CaCO_3$	Tums		
NaCl	Table Salt		
$MgSO_4 \cdot 7H_2O$	Epsom Salts		
CxHyCOONa	Soap		
$KHC_4H_4O_6$	Cream of Tartar		

ANALYSIS:

1. Identify the salts that produce an acidic solution.
2. Identify the salts that produce a basic solution.
3. Why are antacid tablets used for upset stomachs caused by acid indigestion?
4. Identify the neutral salt solutions.
5. Explain why the colors vary for different acids and bases.
6. If a salt forms a basic solution in water, what kind of pH does this solution have? Which ion is in excess, $[H_3O^{+1}]$ or $[OH^{-1}]$? Where do these ions come from?

OUR FINDINGS:

See Section V.

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FLOWER PETAL INDICATORS

Otto Phanstiel

TOPIC:

Acid/Base Indicators

INTRODUCTION:

An *indicator* is a substance that changes color in different solutions, thus "indicating" the nature of the solution. Chemists use indicators to find out whether a solution is acidic or basic and to determine the strength of an acid or base. Different indicators produce a range of different colors in various solutions. In this project, you will extract the colors from different flowers and observe their actions as natural indicators.

TIME NEEDED:

1 hour

MATERIALS:

4 different-colored flowers (Brightly colored lilies work well, as do blue irises, African daisies, petunias, and asters.)
4 short drinking glasses
20 clear plastic glasses
rubbing alcohol
household ammonia
white vinegar
28% acetic acid (available at photography supply stores)
4 tablespoons
wire mesh strainer
4 eyedroppers

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. Care should be taken not to get ammonia, water, vinegar, or acid solution in eyes. Wear safety goggles while pouring these substances. Wash hands carefully afterward.

PROCEDURE:

1. Enter the names of each type of flower you are using on the Data Table below. Remove the petals from one of the flowers and place them in one of the short glasses. Pour in just enough alcohol to cover the petals. With a spoon, crush the flower against the bottom of the glass in the alcohol until the color begins to bleed into the alcohol. Continue crushing and stirring the petals while you add a bit more alcohol until you have about 50 ml of colored extract.
2. Repeat step 1 with each of the different flowers, making sure to use a clean spoon for each so as not to mix the colors.
3. Carefully pour one of the petal mixtures through a wire strainer into a plastic glass to obtain a pure extract. Press the petals against the mesh to squeeze out all the liquid. Discard the used petals and wash the strainer. Repeat with each of the remaining petal mixtures, washing the strainer each time to avoid mixing colors. Note the colors of the extracts on the Data Table.

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DATA TABLE

Name of flower	Extract color	Color in water	Color in base (ammonia)	Color in weak acid (vinegar—5% acetic acid)	Color in stronger acid (28% acetic acid)

4. Set up 4 empty plastic cups behind each extract. Pour about 30 ml of water in the first, ammonia in the second, vinegar in the third, and photographer's acetic acid in the fourth.

5. Using an eyedropper, put a few drops of the first flower extract into the 4 different solutions. Observe color changes and record them on the Data Table. Repeat with each of the flower extracts using a new eyedropper each time to make sure the colors do not mix.

ANALYSIS:

1. Why do you think you use water as the first solution?

2. For each extract, were the colors different in the base and acids than in the water? Based on your answer to question 1, which of the flowers acted as indicators?

OUR FINDINGS:

See Section V.

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CABBAGE PATCH CHEMISTRY

Carol B. Collins

TOPIC:

pH of Common Household Substances

INTRODUCTION:

The substances we encounter in everyday life are usually categorized according to their functions, for example, things good to eat, things that have medicinal value, things that are cleaning agents, or things that are used as cosmetics or for personal hygiene. The potential functions of a substance are partially determined by its chemical makeup, one aspect of which is its pH value. The pH scale is used by scientists to describe whether a substance is acidic (pH 1-6), neutral (pH 7), or basic (pH 8-14). In this experiment you will test the pH of different kinds of household products to see whether there seems to be a relationship between the pH value of a substance and its common uses.

TIME NEEDED:

40 minutes

MATERIALS:

1 head of red cabbage
1 electric blender
eyedropper or straw
1 large wire strainer
1 small bowl
plastic cups
spoons or plastic stirrers
3 samples each from 4 different groups of household substances: foods, cosmetics and hygiene products, cleaning products and medicines. The samples must be liquid or soluble in water.

Safety Precautions

Adult supervision necessary. Please read and copy the safety precautions at the beginning of this book. Many household products contain dangerous chemicals. Ask you teacher to help you select appropriate products. Test substances from their original containers and read all safety precautions on the labels before beginning the experiment.

PROCEDURE:

Part A. Preparing the Indicator

Acid/base indicators are substances that signal the presence of different pH values by changing color. Some plants contain pigments that do this. You can use red cabbage to prepare an effective acid/base indicator.

1. Tear three or four red cabbage leaves into pieces and place in blender.
2. Add approximately 1 cup (250 ml) of water.
3. Blend until cabbage is well chopped and juice mixes with water.
4. Pour mixture through wire strainer into bowl, removing cabbage pieces.

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Part B. Testing pH

1. Select at least three items from each group (foods, beauty and hygiene products, medicines, and cleaning products) to test.
2. Place a small amount of one of the substances in a plastic glass. If the substance is not liquid, dissolve it in a little water.
3. Using the medicine dropper or a straw with your finger over the end, add 2-3 squirts of cabbage juice to the substance to be tested. Note the color and write the name of the substance in the proper column on the Data Table.
4. Continue until all substances have been tested and listed on the Data Table.

DATA TABLE

Acids		Neutral	Bases	
Pink (pH 2-3)	Lavender (pH 4-5)	Blue/Purple (pH 7)	Yellow (pH 8-9)	Green (pH 10-11)

ANALYSIS:

1. On a separate sheet of paper, group the products you tested in their function categories, and next to their names, write the color and pH range your test showed for each product.
2. Look for patterns among the substances you tested. What colors were produced when the foods were tested? The beauty and personal hygiene products? The medicines? The cleaning products?
3. Make a statement about the usual pH of each type of substance and whether it tends to be acidic, basic or neutral—or if there seem to be several different pH values in a single category.

OUR FINDINGS:

See Section V.

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PLANT INDICATORS FOR ACIDS AND BASES

Carole R. Goshorn

TOPIC:

Acid/Base Indicators

INTRODUCTION:

Scientists use a pH scale as a measure of acidity (the hydrogen ion concentration of a solution). Solutions having a pH less than 7 are considered acidic; those with a pH greater than 7 are basic. Frequently, scientists use indicators, such as litmus paper, to determine pH. (Indicators are substances that signal the occurrence of a chemical reaction by a color change.) Many plants also contain pigments that have acid/base indicator properties. In this experiment you will prepare standard acidic and basic solutions of known pH values, observe and record indicator colors for each pH value tested, and determine the pH of an unknown solution by comparing it to the indicator colors you have prepared.

TIME NEEDED:

preparation by teacher 50 minutes
to completion 45 minutes

MATERIALS:

For teacher:
- ½ pint blueberries
- ½ pint radish skins
- ⅛ head red cabbage
- water
- 400-ml beaker, or saucepan
- 3 labeled dropper bottles
- Bunsen burner, hot plate, or stove
- 0.1M HCl (*.3 ml of 12M HCl added to 1 l distilled water)
- 0.1 M NaOH (4.00 g NaOH added to 1 l distilled water)
- vinegar (Unknown A)
- diluted household ammonia (Unknown B) (1 part ammonia to 3 parts distilled water)

For student:
- 12 small test tubes and test tube rack
- marking pencil
- 10-ml graduated cylinder
- dropper pipette
- distilled water

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

Part A. Teacher Preparation of Indicators

1. Indicator solutions should be fresh for procedure. Store for no more than two days in refrigerator.

2. In a 400-ml beaker, place about ⅛ head of chopped red cabbage and fill beaker with distilled water to about 300 ml total volume.

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3. Heat (do not boil) for about 40 minutes.
4. Pour the indicator solution into labeled dropper bottles.
5. Repeat steps 2-4 for blueberries and for radish skins.
6. Prepare the solutions of HCl and NaOH. To prepare the HCl solution add 8.3 ml of 12M HCl to 500 ml distilled water. Stir and then bring level of water up to 1000 ml.

Part B. Student Preparation and Testing of Standard Solutions

1. Calibrate the pipette by counting how many drops are needed to increase the volume in the graduated cylinder by 1 ml. To find how many drops are needed to deliver 0.5 ml, divide the number of drops determined above in half.
2. Label 5 clean test tubes 1-5.
3. Into tube #1 add 5 ml O.1M HCl (pH = 1).
4. Using the pipette, transfer 0.5 ml of the solution in tube #1 to tube #2.
5. Using the graduated cylinder, add 4.5 ml of distilled water to tube #2 and mix well. Tube #2 now contains a 1/10 dilution or 0.01M HCl (pH = 2).
6. To prepare tube #3, remove 0.5 ml from tube #2. Then add 4.5 ml distilled water to tube #3. The concentration of tube #3 is now 1/10 that of tube #2, or 0.001M (pH = 3).
7. Prepare test tubes #4 and #5 in the same manner, always transferring 0.5 ml from the previous test tube and adding 4.5 ml distilled water.
8. Rinse the dropper pipette with distilled water after preparing test tubes #1-#5.
9. Now label 5 clean test tubes 6-10. Follow the dilution procedures in steps 3-8, but start with a 0.1M solution of NaOH (pH = 13) in tube #6. Transfer 0.5 ml of that solution into tube #7. Add 4.5 ml of distilled water to tube #7 (which will have a pH of 12), and so on.
10. Now add three drops of the same indicator—blueberries, radishes, or cabbage—to each test tube (#1-#10) and record the resulting solution colors on the Data Table. Save the solutions for *Part C*.

DATA TABLE

Indicator Used: _____

	Test Tube	Solution Color with Indicator	pH
Acid Standard Solutions	#1		1
	#2		2
	#3		3
	#4		4
	#5		5
	Test Tube	Solution Color with Indicator	pH
Base Standard Solutions	#6		13
	#7		12
	#8		11
	#9		10
	#10		9

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Part C. pH of an Unknown Solution

1. Obtain 5 ml of an unknown solution your teacher has prepared (Unknown A) in a clean test tube and add three drops of indicator solution. Match the color of the unknown solution to one of your standard solutions, record the tube number and the pH value.
2. Repeat step 1, using your teacher's other unknown solution (Unknown B). Record the tube number and pH of the matching standard solution.
3. Pour all solutions down the drain.

ANALYSIS:

1. What color was the indicator solution you began with? What range of colors did you get when it was added to an acid ranging from pH 1-5? When it was added to a base ranging from pH 13-9?
2. Based on your results, what was the approximate pH level of Unknown A? Was it an acid or a base? weak or strong?
3. Based on your results, what was the approximate pH level of Unknown B? Was it an acid or a base? weak or strong?
4. Compare your results with those of students using different indicators. Did you all identify the same pH levels for Unknowns A and B? Explain.

OUR FINDINGS:

See Section V.

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WHAT MAKES A GOOD CONDUCTOR

Mary V. McCrary

TOPIC:

Chemical Bonding

INTRODUCTION:

Because electrical current is the free movement of electrons, the way atoms combine in a substance, known as the substance's *bond type*, determines its ability to conduct electricity. In this project, you will test the conductivity of some solids and solutions and relate your results to the bond types of the samples tested.

TIME NEEDED:

45 minutes

MATERIALS:

conductivity apparatus (3 pieces insulated copper wire, 6-V flashlight bulb, socket for bulb, 6-V DC lantern battery)
aluminum foil
mylar (from helium balloon)
soapless steel wool
glass rod
wooden stick
paper clip
charcoal stick
graphite pencil "lead"
plastic ruler
small piece of rubber tubing
small piece of stripped copper wire
1 tbs table salt
1 tbs baking soda
1 tbs granulated sugar
1 l water
small saucepan
stove or hot plate

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

Part A. Set Up

Set up the conductivity apparatus as shown in the illustration.

Part B. Metallic and Covalent Bonds

Elements classified as metals lose electrons easily. In fact, their electrons are free to move among all the atoms in the substance. Atoms in a metallic element or in a compound composed of different metals are held together by attractive forces between the nuclei and these freely moving electrons, and are good electrical conductors. These substances are said to have *metallic bonds*.

Elements classified as nonmetals and compounds composed of nonmetallic elements are held together by *covalent bonds*. Atoms in these substances share one or more specific pairs of

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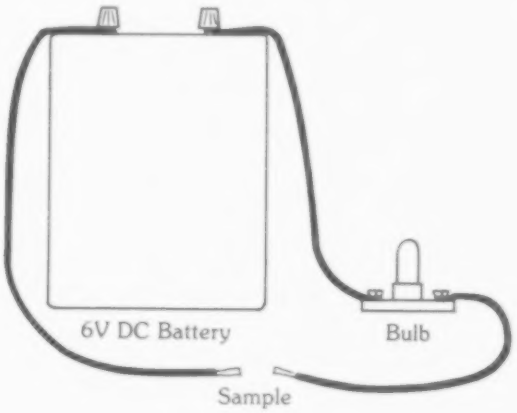
electrons. Their electrons are localized—they cannot move freely throughout the substance, and thus these materials do not conduct electricity.

A few elements exhibit properties of both metals and nonmetals. They conduct electricity in some forms and not in others. In their conductive form they have metallic bonds; in their nonconductive forms they are held together by covalent bonds.



1. Test the conductivity of the solid substances listed on Data Table A. To do this, touch both wires of your testing device to each sample. If the bulb lights up, the sample is a conductor. Note the results by writing "yes" or "no" in the column labeled "conductivity."

DATA TABLE A

Substance	Conductivity	Bond type: Metallic or covalent	Exhibits properties of metal or nonmetal
1. glass rod (silicon, oxygen)			
2. aluminum foil			
3. steel wool (iron)			
4. mylar (a polyester—carbon, oxygen, hydrogen)			
5. paper clip (nickel, iron)			
6. plastic ruler (polypropylene)			
7. rubber tubing (1,3 butadiene)			
8. copper wire			
9. charcoal stick (carbon)			
10. wooded stick (cellulose)			
11. graphite pencil "lead" (carbon)			

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2. After you have tested all the samples, go over your results and, in the appropriate column, write whether each substance exhibits properties of a metal or a nonmetal. Note what bond type you think each has.

Part C. Electrolytes and Nonelectrolytes

When a metallic and a nonmetallic element combine to form a compound, a different type of bonding takes place. This is called *ionic bonding*. In this type of bond, atoms of the metal lose electrons, which are acquired by atoms of the nonmetal. Thus, charged particles known as ions are formed—the metals that have lost electrons form positively charged ions, and the nonmetals that have gained electrons form negatively charged ions. Although the compound is made up of charged particles, the numbers of negative and positive particles are always equal. Therefore, the compound is electrically neutral. In its solid form the substance's charged particles are not free to move around so, as solids, compounds with ionic bonds do not conduct electricity. However, when these compounds are melted or dissolved in water, the charged particles (ions) are dissociated, that is, they are separated and free to move about. In solution these compounds are electrical conductors. Substances that conduct electricity in solution are called *electrolytes*, and those that do not, *nonelectrolytes*.

1. For each of the substances listed on Data Table B, test a solid sample for conductivity and note your results on the table.

DATA TABLE B

Substance	Conductivity as a solid	Conductivity in solution	Bond type	Electrolyte or nonelectrolyte
sugar (dextrose: carbon, hydrogen, oxygen)				
table salt (sodium chloride —sodium and chlorine)				
baking soda (sodium bicarbonate— carbon, hydrogen, sodium, oxygen)				

2. Put the tablespoon of sugar into 250 ml of water in a small saucepan and bring the solution to a boil, stirring to be sure it is dissolved. Test the boiling solution for conductivity and note the results on the table.

3. Repeat step 2 for both the table salt and baking soda samples.

4. Based on your results, decide whether you think each of these compounds has ionic or covalent bonds and whether each is an electrolyte or a nonelectrolyte. Note your conclusions on the table.

ANALYSIS:

1. Which of the solids in *Part B* were good conductors? Which were poor conductors? Which of the samples exhibited metallic properties?

2. The wires of your conductivity device are copper that is coated with rubber. Explain the role of each of these substances in your device.

3. Did any of the solid substances in *Part C* conduct electricity? Why or why not? Did any of the solutions conduct electricity? Why do you think the solutions were heated? Which substances are electrolytes?

OUR FINDINGS:

See Section V

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REMOVING SILVER TARNISH

Diane Moore Jernigan

TOPIC:

Replacement by More Active Metals

INTRODUCTION:

Elements classified as metals have an atomic structure in which free electrons drift between atoms in the substances. The greater a particular metal's tendency to lose electrons, the more chemically active that metal is said to be. Corrosion—for example, iron rusting or silver tarnishing—is a result of this tendency of metals to lose electrons. When two metals are in an environment in which electrons are free to flow between them (conducting electrical current), the more active metal will lose electrons and replace the less active metal in the compound (tarnish) that is the product of corrosion. Knowing this, you can set up a test of two metals to determine which is more chemically active. In this project you will test aluminum and silver and, in the process, demonstrate a kind of instant silver "polish."

TIME NEEDED:

45 minutes

MATERIALS:

tarnished silver or silverplate objects
tap water
soap
iron or stainless steel pot large enough to hold silver items (Do *not* use an aluminum pot.)
aluminum foil
tablespoon
baking soda
kitchen stove or hot plate
stainless steel tongs
table salt

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Be careful when using the stove. Use a pot holder when grasping the handles of the hot pot. Do *not* use an aluminum pot for this experiment because it would be destroyed and contaminated by the reaction. Keep table salt away from all silver items.

PROCEDURE:

1. Wash the tarnished silver objects with soap and water to clean off any grease, which might interfere with the reaction.
2. Line the stainless steel pot with a sheet of aluminum foil and fill the pot with enough water to completely cover any silver item.
3. Add 2 tablespoons of baking soda to the water and stir. Place the pot on the stove or hot plate and bring the solution to a boil. (When baking soda dissolves in the water it breaks up into charged particles, called ions, making it a good electrical conductor. Boiling the solution provides heat, which speeds up the rate of any chemical reaction.)
4. When the solution comes to a boil, immerse a silver item completely until it contacts the

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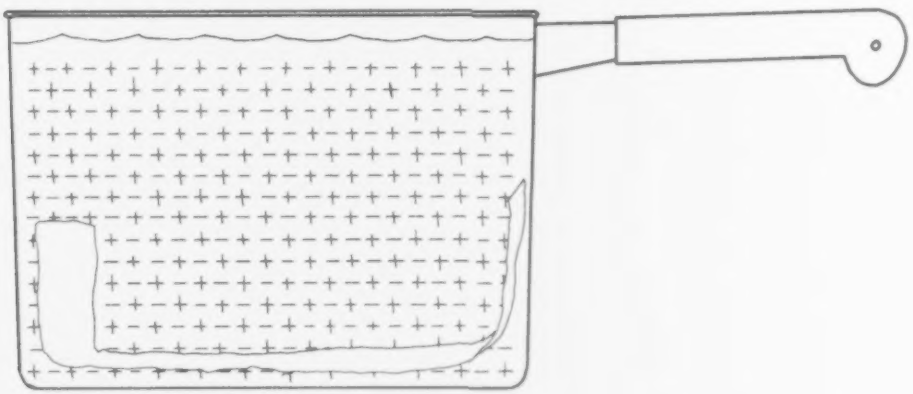
aluminum foil. Use stainless steel tongs to handle the object in the boiling solution, but be careful not to scratch the item.

5. As soon as you observe a change in the silver item, remove it from the pot and wash it off. (It must be washed to remove any baking soda residue.)



6. Repeat the procedure with as many tarnished silver items as desired. If many items are being used, check the aluminum foil periodically and replace it if crumbling occurs.

7. To determine whether all the silver atoms liberated from the tarnish have returned to the silver object or if any have been lost to the solution, you can perform another test. Silver reacts with sodium chloride (table salt) to form an insoluble solid, silver chloride. (This is why table salt should be kept away from silver as much as possible.) After you have removed the silver items and the aluminum foil from the pot, add a tablespoon of salt to the solution. Observe any reactions.

ANALYSIS:

1. What happened to the aluminum foil? What happened to the silver? Based on these results, which metal tends to lose electrons more readily, making it more chemically active, silver or aluminum?

2. What happened to the stainless steel or iron pot during the procedure? What can you conclude from this about how chemically active iron or stainless steel is compared to aluminum? Compared to silver?

3. Why would you need to replace the aluminum foil if you were performing the reaction repeatedly with many silver items? Why should you not use an aluminum pot for the reaction?

4. What happened after you added the salt to the solution? Does a white precipitate form? If so, where do you think the silver atoms from the tarnish are? If there is no reaction, where are the silver atoms from the tarnish?

OUR FINDINGS:

See Section V

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THE STORY OF CALCIUM

Margaret Christoph

TOPIC:

Physical and Chemical Properties of Calcium and Its Compounds

INTRODUCTION:

Calcium is one of the most abundant elements in the earth's crust and one of the most important components of plant and animal matter. Yet, because it is chemically very active, it is never found uncombined in nature. In this experiment you will investigate the properties of this important chemical.

TIME NEEDED:

40 minutes

MATERIALS:

pure calcium
kerosene
phenolphthalein (indicator for a base)
water
balance—triple beam or cent-o-gram
10-ml graduated cylinder
splints
conductivity apparatus (Example: voltmeter; multitestor; or 6-V battery, 3 pieces of 22-gauge wire, bulb, and socket.)
100-ml glass graduated cylinder
Celsius thermometer

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

Part A. Identifying the Physical Properties of Calcium

1. Make sure your hands are dry and then examine a small piece of calcium. By visual observation and feel, determine its color and hardness. Record on Data Table 1.

DATA TABLE 1

Color of calcium: _____	Volume of "dry" kerosene: _____
Hardness: _____	Volume of kerosene + calcium: _____
Conductivity: _____	Volume of calcium: _____
Mass of calcium: _____	Density of calcium: _____

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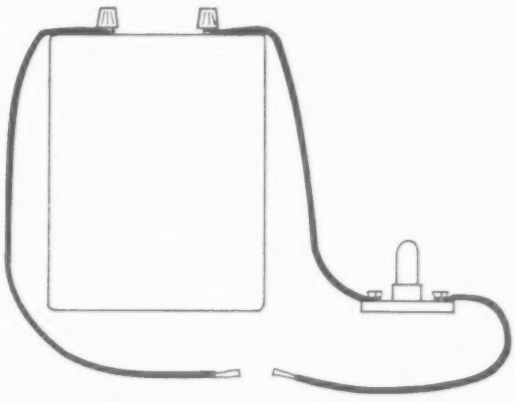
2. If you are using the 6-V battery, set up the conductivity apparatus as shown in the illustration. Using your conductivity apparatus, touch a piece of calcium with the 2 probes. A positive reading on the meter or the bulb lighting indicates the substance is conductive and therefore metallic. Record metallic or nonmetallic on Data Table 1.



3. Determine the density of calcium by using the following procedure:
   a) Measure the mass of several pieces of calcium (about 1 g total) to the nearest 0.01 g on a balance.
   b) Measure 5.0 ml of dry kerosene in a 10-ml graduated cylinder. (To dry kerosene, use several pieces of calcium, which will absorb water, removing it from the kerosene. Decant off the supernatant kerosene, which will now be dry. Dry in this context means that the kerosene no longer contains water. The kerosene will still be in a liquid form.)
   c) Add the calcium.
   d) Measure the new volume.
   e) Find the volume of the calcium by subtracting the volume of the kerosene from the volume of the kerosene + calcium.
   f) Calculate density: mass of calcium/volume of calcium.

Part B. Observing the Reaction of Calcium with Water

1. Measure out 0.8 to 1.0 g calcium to the nearest centigram. Record on Data Table 2.

DATA TABLE 2

Mass of calcium: _____

Volume of water: _____

Temperature before: _____

Temperature after: _____

Temperature change: _____

Calories evolved: (volume of water × temperature change) _____

Calories evolved per gram of calcium: _____
(Calories evolved ÷ mass of calcium)

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2. Measure 60 ml of water in a 100-ml graduated cylinder.
3. Record the temperature of the water.
4. Add the calcium to the water in the graduated cylinder.
5. Invert a test tube over the solution to collect the gas being evolved.
6. Light a splint, then blow out the flame and insert the glowing splint into the inverted test tube.
7. Record your observations. A "pop" indicates the presence of H_2.
8. Again record the temperature of the water.
9. Add several drops of phenolphthalein indicator and observe. (The appearance of a pink or red color indicates the presence of a base. No color change indicates the presence of an acid.)
10. On the Data Table calculate the approximate number of calories per gram of calcium evolved in the reaction of calcium with water. The amount of heat required to raise 1 ml of water 1° Celsius is equal to 1 calorie. Subtract the initial temperature of the water from the final temperature. Multiply the temperature change by the volume of water (in °C × ml water) to get the total number of calories evolved in the reaction. Divide this number by the mass of the calcium to get calories evolved per gram of calcium.

ANALYSIS:

1. Describe the physical properties of calcium. Is it a metal or a nonmetal? What is its density?
2. Describe the reaction of calcium with water. What products are formed? Is the solution produced an acid or a base?

OUR FINDINGS:

See Section V.

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THE CHEMICAL PROPERTIES OF MARBLE

Terry Thompson

TOPIC:

Chemical Properties of Calcium Carbonate

INTRODUCTION:

For centuries artists and architects have used marble (calcium carbonate) to create buildings and statues, many of which are now seriously affected by chemical pollution. In this exercise, you will study the chemical properties of marble and see why it is damaged by pollution.

TIME NEEDED:

45 minutes

MATERIALS:

marble or limestone
powdered marble (calcium carbonate)
bromothymol blue (indicator for carbon dioxide)
phenolphthalein (indicator for a base)
2 50-ml beakers
Erlenmeyer flask
glass tubing
rubber tubing
dilute hydrochloric acid or vinegar
1-hole stopper
eyedropper
spatula
piece of white paper

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. Do not use concentrated hydrochloric acid.

PROCEDURE:

Part A

1. Using an eyedropper, place several drops of dilute hydrochloric acid or vinegar on a piece of marble or limestone.
2. Record results.

Part B

1. Study the illustration to see how to set up this test. Connect the stopper, glass tube, and rubber tubing so they are ready for placement. Pour the bromothymol blue into a beaker.
2. Place two or three spatulas of powdered marble (calcium carbonate) in an Erlenmeyer flask.
3. Add 50 ml weak (1.0N) hydrochloric acid or vinegar.
4. Immediately cap the flask with the stopper to which you have attached rubber tubing.
5. Place the other end of the rubber tubing into the beaker of bromothymol blue. Place a piece of paper beneath the beaker.
6. Observe the bromothymol blue and record your observations.

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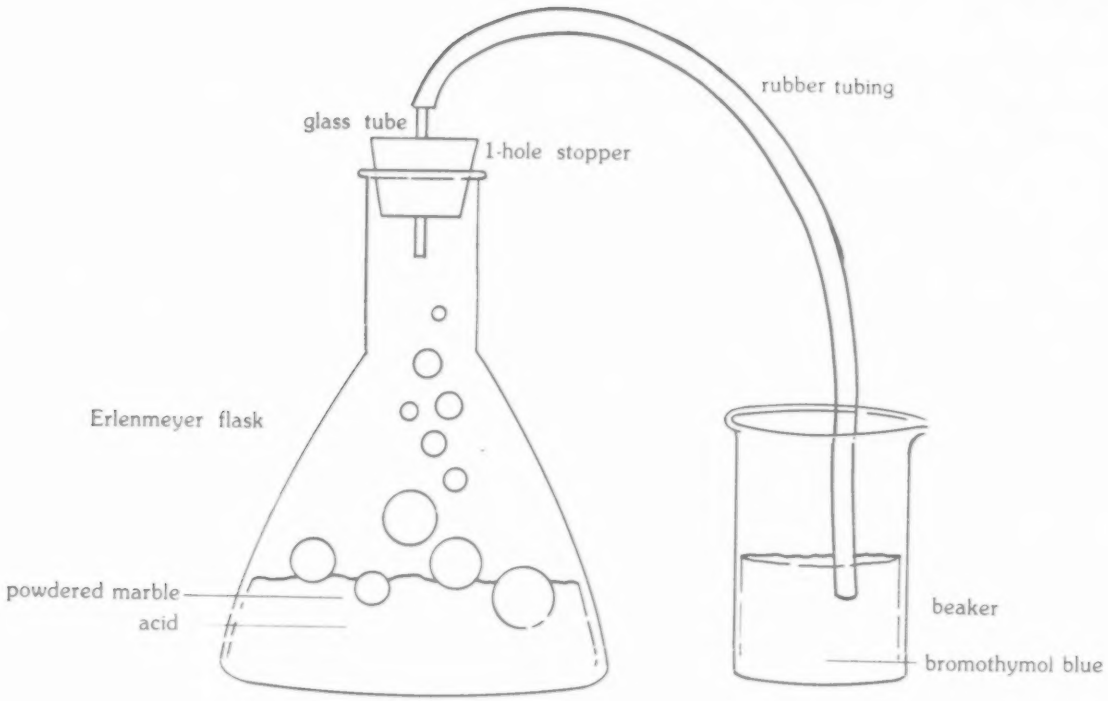

Part C

1. Mix a spatula of powdered marble and 50 ml water in a 250-ml beaker.
2. Add several drops of phenolphthalein to 50 ml water in a separate beaker. Then add this solution to the calcium carbonate solution in the 250-ml beaker. Observe.
3. Add 5–10 drops weak hydrochloric acid or vinegar to the solution.
4. Observe. Record your observations.

ANALYSIS:

1. What happens when acid is added to marble or limestone?
2. What gas is given off when acid is added to powdered marble (calcium carbonate)?
3. What happened when you added phenolphthalein to the calcium carbonate solution? Is calcium carbonate acidic, basic, or neutral?
4. What effect would you predict that acid rain might have on marble statues, buildings, and grave markers?

OUR FINDINGS:

See Section V.

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ELECTROGRAPHIC METAL DETECTION

Mary Ethel Parrott, S.N.D.

TOPIC:

Electrographic Identification of Iron, Copper and Lead

INTRODUCTION:

Electrography is a method of qualitative analysis employed by chemists and forensic scientists. An electrical current is passed through a sample in contact with an electrolyte. The original sample dissociates and reacts with the electrolyte to form an insoluble compound, visible as a colored precipitate. A classic example of the forensic use of electrography was the investigation of a crime during which a copper electrical wire had been severed. Electrographic analysis revealed traces of copper on a hatchet in a suspect's possession. In this project, you will use electrography to identify the presence of different metals in known and unknown samples.

TIME NEEDED:

2 hours

MATERIALS:

small flat samples of iron, copper and lead
small flat sample of galena
small flat samples of one or more of iron sulfide, chalcocite, magnetite
small flat samples of your choice; include coins, small pieces of hardware, bits of minerals found in your area, etc.
aluminum sheet
insulator base (e.g., sheet of plastic or wood)
6-V lantern battery
alligator clip
banana plug
2 pieces of electrical wire, each 15 cm long
razor knife
tweezers
filter paper
2 % potassium chromate solution
10% potassium ferrocyanide solution
10% potassium ferricyanide solution

Safety Precautions

THIS EXPERIMENT MUST BE SUPERVISED BY A CHEMISTRY TEACHER. Please read and copy the safety precautions at the beginning of this book. The solutions must be prepared by a teacher. Solutions should be treated as poisonous and corrosive. Wear safety goggles, lab apron and gloves. Wash your hands when you finish the experiment. If any of the solution contacts your skin or clothing, immediately wash with plenty of water. Clean up all residue and containerize for proper disposal. Dispose of all chemicals in accordance with all local, state and federal laws.

PROCEDURE:

1. Set up the electrographic apparatus as shown in the illustration. First, strip about 1 in. off each end of both wires. Attach the banana plug to one wire and the alligator clip to the other.

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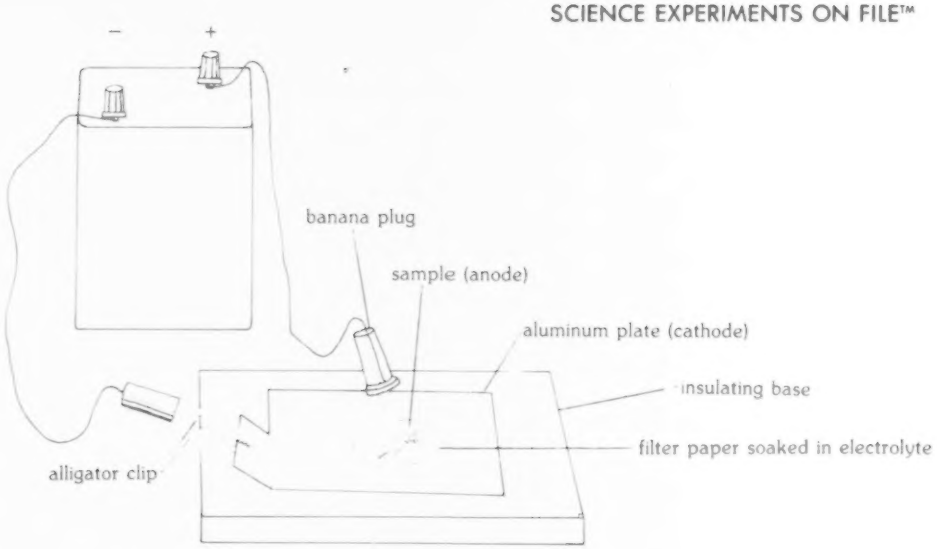

Attach the other end of the banana-plug wire to the positive pole of the battery and the alligator-clip wire to the negative pole. Test the connections to see that they are firm. Place the aluminum sheet on top of the insulating base and attach the alligator clip to one edge.

2. Holding it with the tweezers, soak a piece of filter paper in potassium ferrocyanide solution. Gently wave the wet paper in the air for about 30 seconds so that excess liquid evaporates. Place it on the aluminum sheet. Then place the copper sample on top of the filter paper and hold the banana plug against the copper sample. Apply pressure to make good contact for 30 seconds. Break the contact and remove the sample. Remove the paper carefully with the tweezers and rinse in gently running water until all of the color from the electrolyte solution has been washed out. Examine the filter paper for a colored precipitate indicating the presence of copper. Record the color on the Data Table.

DATA TABLE

Material Tested	Solution on Filter Paper	Color of Precipitate
copper	potassium ferrocyanide	
iron	potassium ferrocyanide	
iron	potassium ferricyanide	
lead	potassium chromate	
galena	potassium chromate	
your choice:		
your choice:		
your choice:		

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3. Repeat the test with iron, again using potassium ferrocyanide solution on the filter paper. Wipe off any excess solution that has accumulated on the aluminum sheet, and test iron again, this time using potassium ferricyanide. Then test a lead sample, moistening the filter paper with potassium chromate solution. Each time you change solutions, wipe off the aluminum sheet.
4. Test the sample of galena in place of a metal sample. Look for indication of the presence of lead in the sample. Record your results on the Data Table.
5. Test the other mineral samples or metallic items you have chosen for the presence of copper, lead, and iron. Record your results on the Data Table.

ANALYSIS:

1. What color indicated the presence of copper? What color indicated the presence of iron? What color indicated the presence of lead?
2. Is there lead in galena? How do you know?
3. What metals, if any, were present in the sample(s) you tested of iron sulfide, chalcocite, and magnetite? How do you know?
4. Were you able to identify metals present in any of your other samples? What were they, and how did you find them?

OUR FINDINGS:

See Section V.

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THE TEST TUBE MYSTERY

Valeria Alston

TOPIC:

Observing Chemical Reactions; Using Logical Deduction

INTRODUCTION:

Chemists, like detectives, attempt to identify unknowns through a process of careful and creative analysis. This often involves observing reactions involving unknown substances and comparing them with reactions of known substances. In this lab, you will try to identify ten different chemical compounds by reacting them with each other, observing the results, and comparing the results with the known characteristics of some common chemicals.

TIME NEEDED:

2 hours

MATERIALS:

spotting plate
red and blue litmus paper
box containing 10 dropping bottles of solutions numbered in sequence from 1 to 10. In each bottle will be a .1M solution of one of the following compounds:

Name	*Compound Type*
ammonium chloride NH_4Cl	salt
barium chloride $BaCl_2$	salt
copper sulfate $CuSO_4$	salt
hydrochloric acid HCl	acid
potassium iodide KI	salt
sodium bromide NaBr	salt
sodium hydroxide NaOH	base
sodium sulfide Na_2S	salt
sulfuric acid H_2SO_4	acid
silver nitrate $AgNO_3$	salt

Safety Precautions

THIS EXPERIMENT MUST BE SUPERVISED BY A CHEMISTRY TEACHER. Please read and copy the safety precautions at the beginning of this book. The solutions must be prepared by a teacher. *All* solutions should be treated as if they were poisonous and corrosive. If you spill some of any solution on yourself, wash it off immediately with large amounts of water. Avoid inhaling fumes. Wear safety goggles, lab apron, and gloves. Clean up all residue and containerize for proper disposal. Dispose of all chemicals in accordance with all local, state and federal laws.

PROCEDURE:

1. Your goal is to identify which solution is in each bottle. You will figure this out by testing each solution with litmus paper and by combining all possible pairs of the solutions (#1 with #2, #1 with #3, etc.). After describing each reaction on the Data Table and thinking carefully about the facts listed in the ANALYSIS section, you should be able to identify each solution.

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2. First, put two drops of solution #1 in the depression of the spotting plate. Do not poke the end of the dropping bottle into the pool on the spotting plate. Screw the top back on the bottle tightly after you have used it.

3. Test solution #1 with red litmus paper and then with blue. Write the result in the top box on the Data Table. If the solution turned red litmus paper blue, write *R to B*. If it turned blue litmus paper red, write *B to R*. If there was no reaction, write *NLR*.

DATA TABLE

(Litmus paper test results recorded in boxes on far right.)

Keys: Red Litmus to Blue—R to B
Blue Litmus to Red—B to R
No Litmus Reaction—NLR
Color of Precipitate—Color PPT
No Reaction—NR

Sol. #	Names of Solutions	1	2	3	4	5	6	7	8	9	10
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

4. Wash and rinse the spotting plate. Then put two drops of solution #2 on the plate, test it with red and blue litmus paper, and note the results on the Data Table in the far right box of horizontal row #2.

5. Now combine two drops of solution #1 with two drops of solution #2 on the plate. Observe the reaction and describe it in the box on the Data Table where vertical column #1 meets horizontal row #2. For example, if a white precipitate formed when you mixed the two solutions, write *white PPT*. If nothing happened, write *NR*.

6. Continue in this way until you have filled in every box on the Data Table. This means you will have tested each individual solution with litmus paper and will have combined all possible pairs of the solutions. Remember not to touch the top of any bottle to the plate, to wash and rinse the plate after each combination, and to screw the bottle caps on carefully after each use.

ANALYSIS:

1. Compare the observations recorded on your Data Table with the following:
   a) Acids will turn blue litmus paper red.
   b) $CuSO_4$ solutions are blue.
   c) Bases will turn red litmus paper blue.

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d) Acids will react with Na_2S to release a gas, hydrogen sulfide, which smells like rotten eggs—AND IT IS VERY POISONOUS—SO BE VERY CAREFUL.
e) If a base is mixed with NH_4Cl, the odor of ammonia (NH_3) is given off. Ammonia vapor will turn damp red litmus paper blue.
f) $AgNO_3$ will react with halogen-(Br, Cl or I) containing compounds to form white or yellowish precipitates.
g) $BaCl_2$ will react with H_2SO_4 and $CuSO_4$ to form a white precipitate, $BaSO_4$.
h) $CuSO_4$ gives an orange-yellow precipitate when mixed with KI, but doesn't give a precipitate with NaBr.
i) A white cloudy precipitate, $Ba(OH)_2$, forms when an excess of NaOH is added to $BaCl_2$.
j) HCl will react with $AgNO_3$ to produce a white precipitate, AgCl.

By using logical reasoning and the process of elimination, you should be able to identify each solution. Write its name next to its number on the Data Table.

2. After you have identified all the solutions, write balanced equations for each of the reactions you performed.

OUR FINDINGS:

See Section V.

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ELECTRICAL CHARGES IN COLLOIDAL SOLUTIONS

Valeria Alston

TOPIC:

Electrophoresis

INTRODUCTION:

Electrophoresis is an electrochemical process in which electrically charged colloidal particles (those larger than molecules but still too small to be viewed through a standard microscope) migrate toward the oppositely charged electrode when two electrodes are placed in a solution and current is applied. Electrophoresis is frequently used in protein analysis, since particles of different sizes and different charges migrate at different rates and thus separate out. You can also observe the process with other materials, such as the iron chloride used in this demonstration.

TIME NEEDED:

½ hour preparation
1½ hours first observations
24 hours to final observations

MATERIALS:

9-V battery or 9-V DC adapter (See the PROCEDURE section for notes on how to make the adapter a safe source of current.)
scissors
22-gauge wire
wire strippers
alligator clips
U-tube
ringstand with clamps
filter paper
triple beam balance scale
32g iron (III) chloride
stove, hot plate, or bunsen burner to boil water
250-ml beaker
2 pencil leads (or two short pencils prepared as in step 7 of *Part A*)
matte knife

Safety Precautions

THIS EXPERIMENT MUST BE SUPERVISED BY A CHEMISTRY TEACHER. Please read and copy the safety precautions at the beginning of this book. Iron chloride will irritate your skin. Wear safety goggles, lab apron, and gloves. Wash your hands when you finish the experiment. Clean up all residue and containerize for proper disposal. Dispose of all chemicals in accordance with all local, state and federal laws.

PROCEDURE:

Part A. Preparing a DC Adapter and Pencil Leads for Use

By completing the following steps, you can use a DC adapter to provide a safe source of power.

1. Cut off the end of the adapter lead as shown in figure 1.
2. Separate the wires on the adapter at least 4 inches as shown in figure 2.
3. Strip 1 inch of the ends of the cut wires as shown in figure 3.

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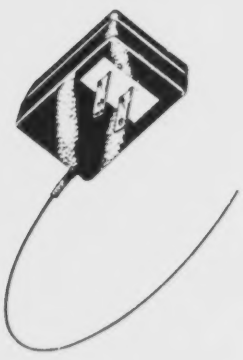

figure 1

figure 2

figure 3

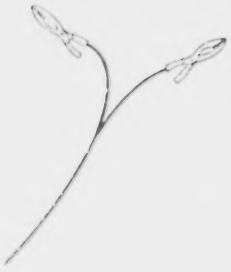

figure 4

4. Attach two alligator clips to the stripped wires as shown in figure 4.
5. Determine which is the positive pole of the adapter.
6. If you are using a battery, connect the alligator clips to 2 pieces of stripped wire and connect to the battery.
7. Sharpen two short pencil lengths at both ends so a good portion of graphite is exposed. Use the matte knife to strip all paint from their sides.

Part B. Performing the Experiment.

1. Put on your laboratory apron, goggles, and plastic gloves.
2. Set up ringstand and U-tube as shown in figure 5 and heat 250 ml of water.

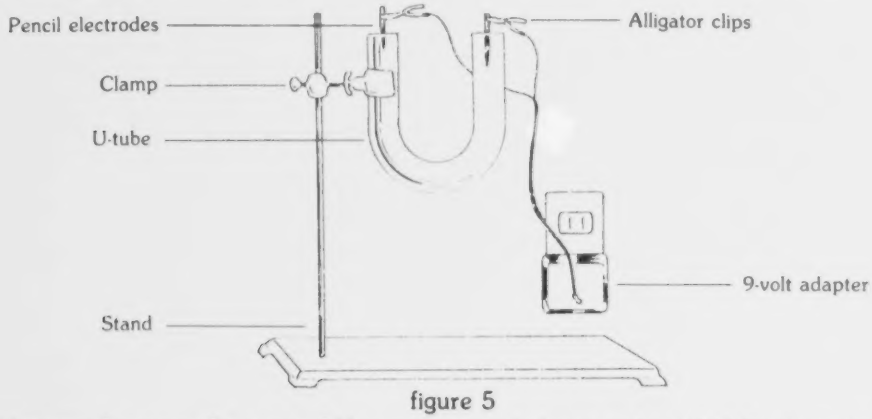

figure 5

3. Measure the mass of a piece of filter paper on a balance scale. Add 32g of iron (III) chloride to the filter paper on the balance. Then put the iron (III) chloride in a 250-ml beaker.
4. Add 200 ml of boiling water to the beaker with the iron (III) chloride. This will form the iron (III) hydroxide colloidal solution.
5. Partly fill the U-tube with the iron (III) hydroxide colloidal solution.
6. Insert the pencil lead electrodes into the solution in the U-tube as shown in figure 5. Connect the electrodes to the DC adapter or battery as shown.
7. After the current has been on for 30 minutes, observe the liquid carefully. Record your observations.
8. Observe the colloidal solution in the U-tube 1 hour later. Has there been any change? If there has been movement in the tube, observe and record the direction of the movement.
9. Let the current remain on for another 24 hours and observe again. Record your observations.

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ANALYSIS:

1. Describe what changes you observed in the tube after ½ hour, after 1½ hours, and after 1 day.
2. Did the boundary between the dark liquid and the light liquid move toward the positive electrode or the negative electrode?
3. The dark liquid is made up of colloidal iron (III) hydroxide particles. Based on your observations, what charge do these particles have?

OUR FINDINGS:

See Section V.

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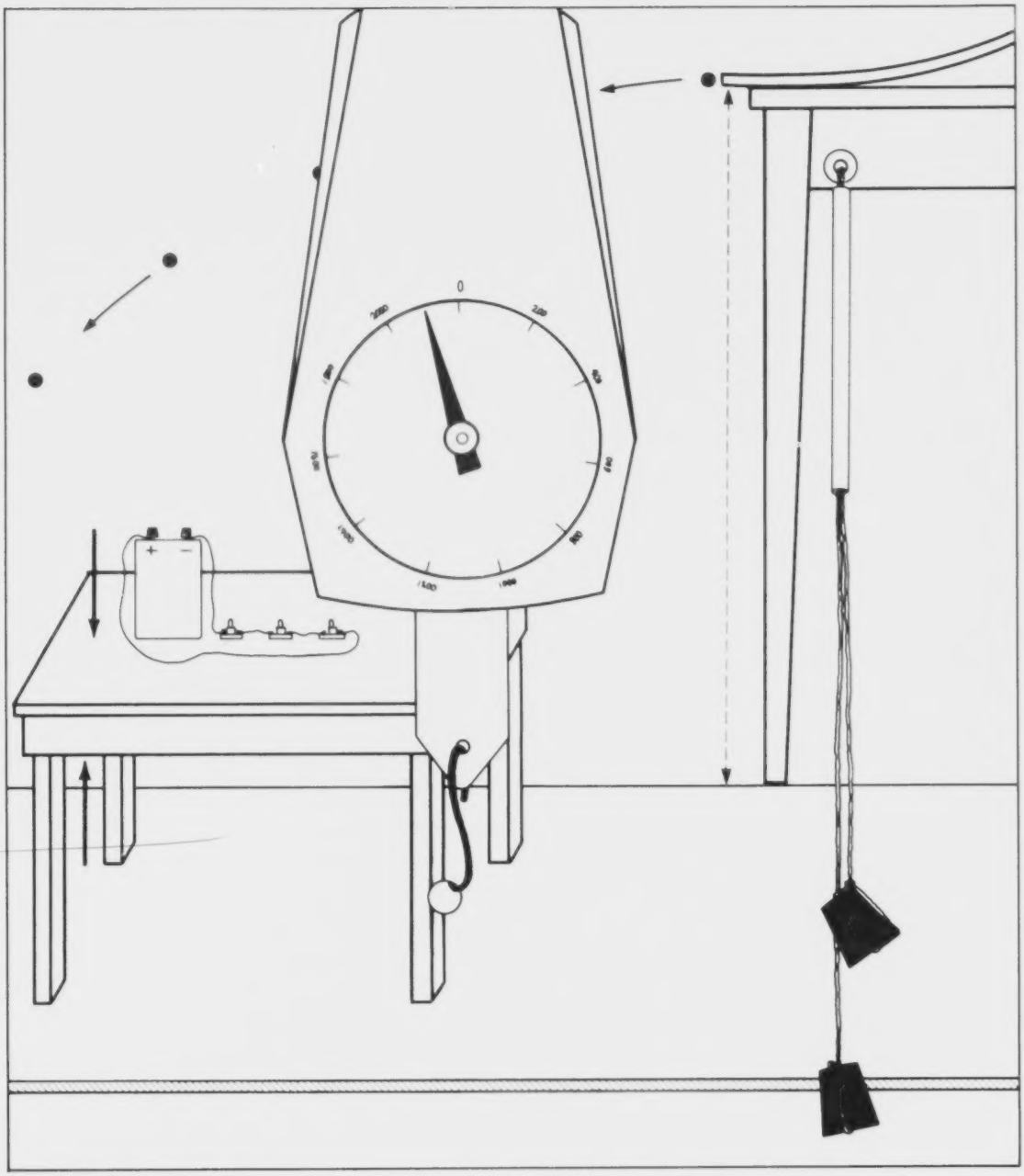
IV.
PHYSICS



UNIFORM MOTION

Charles Lang

TOPIC:

Motion

INTRODUCTION:

The everyday world is full of motion—a leaf falling, a dog running. Scientists define *motion* as a change in the position of an object relative to a reference point. If you were to run in a straight line past several objects, each the same distance apart, and you passed each in the same amount of time and covered the distance at the same speed, you would have uniform motion. In this project you will observe the motion of two different objects and then graph their velocities to show the relationship between time, distance, and velocity.

TIME NEEDED:

1 hour

MATERIALS:

2 slow-moving battery-operated toy vehicles
meter stick or ruler
stopwatch or watch with second hand
paper to make 2 2-meter strips or 4 meters of adding machine tape
cellophane tape or adhesive tape
felt pen

Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

1. Tape together the sheets of paper to make 2 2-meter strips or use 4 meters of adding machine tape. Tape sheets to floor or flat surface. You will run the toys along these.
2. Choose a partner to help you with this experiment. Your partner will hold the watch and call out the seconds while you mark the vehicles' progress.
3. Start the first vehicle's motor before you place it on the strip. Have your partner tell you when to start the vehicle. As your partner calls out each second, mark the vehicle's position at every *other* second—2, 4, 6, etc., using the same reference point on the vehicle to ensure consistent results. Continue until the vehicle reaches the end of the strip. Label the strip with the name of the vehicle and number each second's progress.
4. Repeat step 3 with the other vehicle.

ANALYSIS:

Measure how far the first toy traveled every two seconds. Then measure how far the second toy traveled every two seconds. Record your data on the Data Table below.

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DATA TABLE

	Time (t) (sec)	Total distance (d)	Distance covered during interval (Δd)	Speed = $\frac{\Delta d}{\Delta t}$ (2 sec)
Toy 1	0			
	2			
	4			
	6			
	8			
	10			
	12			
			Avg spd =	
Toy 2	0			
	2			
	4			
	6			
	8			
	10			
	12			
			Avg spd =	

To calculate the speeds, divide the distance covered in the time interval (Δd) by the time interval (2 sec). For example, if your toy covered 4.8 cm between times 2 and 4 sec, 4.8 cm/2 sec = 2.4 cm/sec. To obtain the average speed, add all the speeds and divide by the number of intervals for which they have been calculated.

If all the speeds recorded were exactly equal the toys would be said to have uniform motion. Due to some measuring error, and perhaps to slight fluctuations in the toys' motions, you will probably find slightly differing speeds. The averages that you take give you some idea of what the speed of the toy would be for its ideal (uniform) motion.

You can now graph the motion of the toys, first showing the actual measurements you recorded, and then drawing a line that approximates the toys' uniform motion.

Choose a scale (spacing) for your information so that your graph will take up at least half the graph paper. Lay off time intervals along the horizontal axis of the graph. Lay off the total distances traveled along the vertical axis. The beginning of each scale is the lower left-hand corner of the graph. You should plot both toys' data on the same graph. Refer to the sample graph below if you have questions. Plot points for each measurement of each toy's progress. Use a different symbol for each toy, for example, a small circle for Toy 1 and a solid dot for Toy 2. Now, using your best judgment, draw a pencil line near the points for each toy that best approximates the uniform motion of the toys.

1. Does the first toy have uniform motion? That is, does it move approximately the same distance every two seconds? (The distance will never be precisely the same.) Does the second toy have uniform motion?
2. In what way does the sample graph show uniform motion? Does your graph of your toys also show uniform motion?
3. Which of your toys had the greater speed? How does your graph show this?
4. Earlier, you computed the average speeds of the toys by adding up the speeds in each interval and dividing by the number of intervals. Looking at your graph and Data Table, can you find another way to compute the toys' average speeds?
5. If the toys did not have uniform motion, but instead were accelerating, what would the graph look like? If the toys were decelerating?

OUR FINDINGS:

See Section V.

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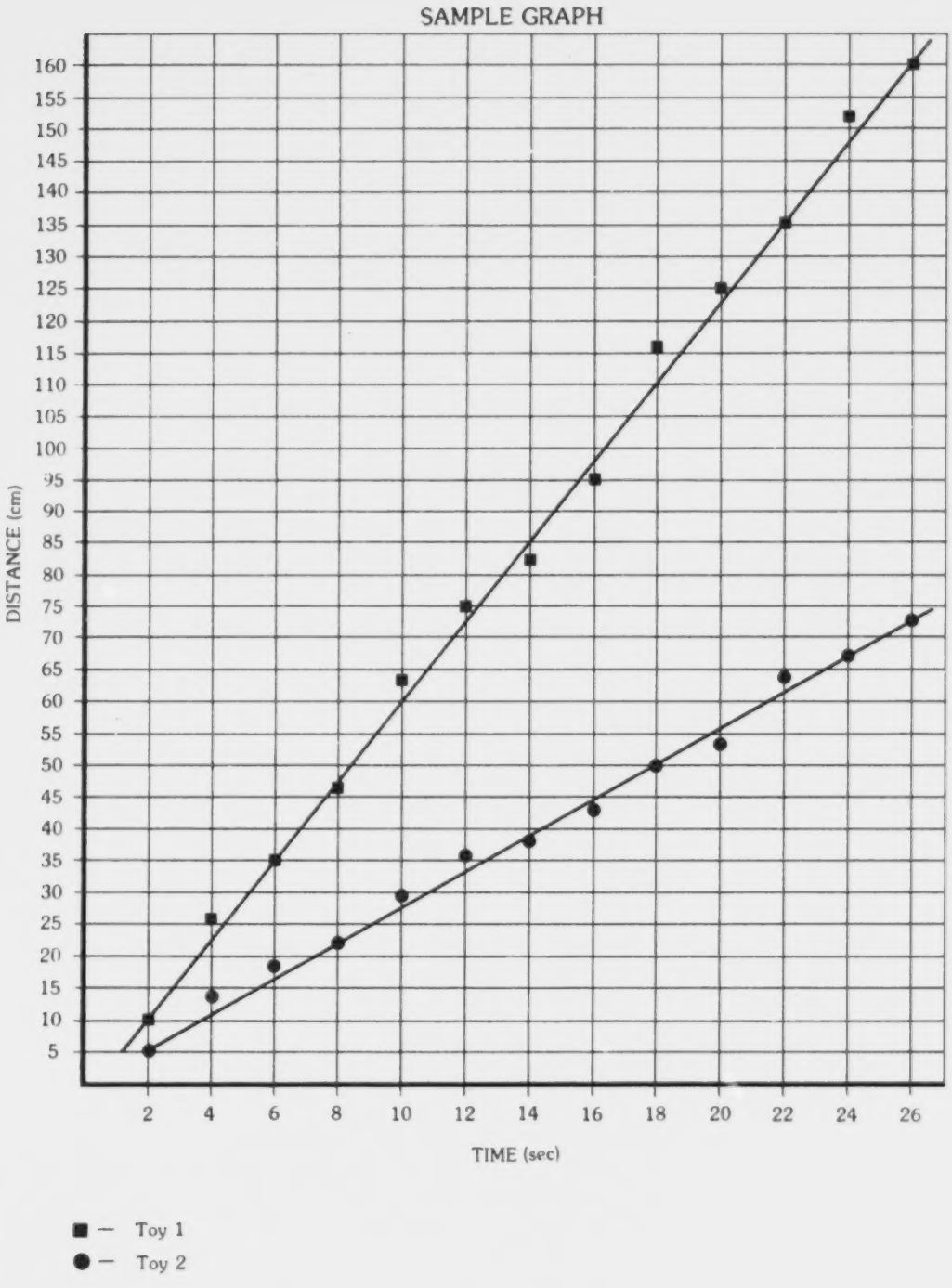
SAMPLE GRAPH
DISTANCE (cm)
160
155
150
145
140
135
130
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
2
4
6
8
10
12
14
16
18
20
22
24
26
TIME (sec)
■ — Toy 1
● — Toy 2

AN INUIT YOYO

Sandra J. Walton

TOPIC:

Centripetal Force

INTRODUCTION:

Centripetal force is the force that keeps objects moving in circles. In this demonstration, you will learn about the properties of this force by using a little-known toy, an Inuit Yoyo.

TIME NEEDED:

20 minutes

MATERIALS:

1 washer or nut
2 m string
2 large corks or 2-holed stoppers
1 unbreakable tube, about 1 cm in diameter and 10 cm in length (the tube of a ballpoint pen works well)

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Allow enough space around you so that the toy does not hit anyone when in motion. Take care that the stoppers or corks used in the toy are tied securely.

PROCEDURE:

1. Cut the string into 2 pieces, one about 2 cm longer than the other. Tie one end of each string to the washer; feed the other end of each string through the tube; and tie on the corks or stoppers as shown in figure 1. Be sure that all knots are secure and have an adult check the apparatus before you attempt to use it.

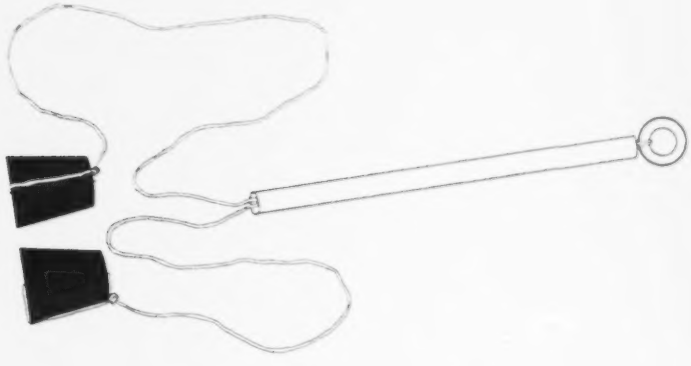

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figure 1

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2. Hold the tube in one hand with the washer end closer to your body. Hold one cork in your free hand and gently swing the other cork in circles. As the swinging cork is rising, release the other cork so it is going down. Start "pumping" the tube up and down to get the corks moving in full circles of opposite direction. (See figure 2.)

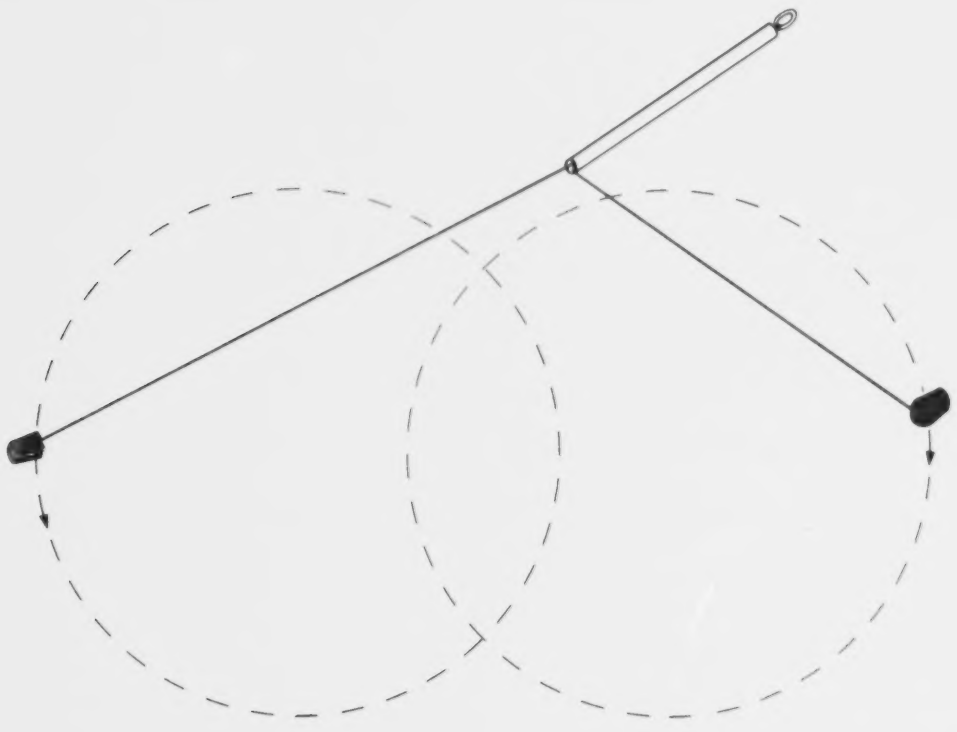

figure 2

ANALYSIS:

1. When the corks are rising, which way do you have to pump your hand?
2. When the corks are going down, which way do you have to pump your hand?
3. What do you call the force needed to keep the corks in circular motion, and in what direction is this force always exerted?

OUR FINDINGS:

See Section V.

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WHERE IS YOUR CENTER OF GRAVITY?

Thomas R. Bross

TOPIC:

Center of Gravity

INTRODUCTION:

The earth pulls down on each particle of an object with a gravitational force that we call weight. Although individual particles throughout an object all contribute weight in this way, the net effect is as if the total weight of the object were concentrated in a single point—the object's center of gravity. In a regular geometric solid with the uniform density, the center of gravity is the object's geometric center. Finding the center of gravity of irregular objects can be tricky. In this project, you will combine practical procedures and calculations to find the center of gravity of your own body.

TIME NEEDED:

30 minutes

MATERIALS:

2 bathroom scales
1 board (long enough for you to lie on and strong enough to support your weight without bending)
2 sturdy chairs of equal height
2 pencils (not round)
tape measure

PROCEDURE:

1. Find a partner to help you with steps 7 and 8 of this experiment. You and your partner can take turns determining each other's center of gravity. You may want to experiment with other individuals as well.
2. Place 2 bathroom scales on 2 chairs as shown in figure 1.

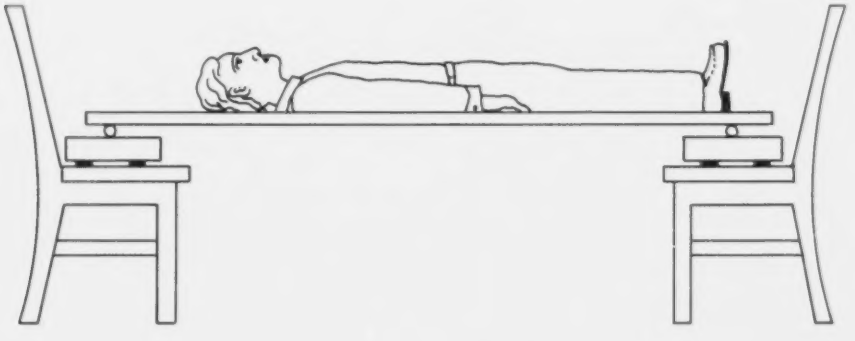

figure 1

3. Lay a pencil horizontally across each scale and place a board on top of the pencils. The

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board should be sturdy enough to support you. The pencils should be shaped so as not to roll easily.

4. Read the scales and record the sum of the readings in the space labeled W_b on the Data Table. This is the weight of the board. You can use pounds or kilograms, but be consistent throughout the experiment.

5. Measure the distance between the pencils, which is considered the length of the board, L. Record this value in the space provided on the Data Table. The length can be measured in inches or centimeters, but be consistent.

6. Now lie on the board with the bottom of your feet just above the position of the pencil on the right. Hold your arms by your sides.

DATA TABLE

W_b	
L	
N_1	
N_2	
h	

7. Have your partner record the scale readings, N_1 (the scale nearer your head) and N_2 (the scale nearer your feet).

8. Finally, stand against a wall and have your partner measure your height, h. The height can be measured in inches or centimetrs, but be consistent. Record this value.

ANALYSIS:

Figure 2 shows the system made up of the chairs, scales, body, and board, with broad arrows indicating lines of force acting on the system. W_b and W_p—the weights of the board and person due to gravity—can be assumed to act through their respective centers of gravity as explained in the introduction. N_1 and N_2—the readings of the scales—represent the upward forces exerted at those points by the pencils that support the board and body. The system is motionless; therefore, it is in *equilibrium*. Certain principles of physics regarding the state of equilibrium will allow you to calculate X, the distance from the right pencil to the person's center of gravity.

The first condition of equilibrium is that upward and downward forces balance. The downward forces W_b and W_p are the weights of the board and the person respectively. There must also be an upward force exerted at the board's two points of contact with the chairs, the pencils, otherwise the body and board would be falling freely toward the center of the earth. The readings on the scales—N_1 and N_2—give the magnitude of those upward forces at these points. Therefore we can write

$$N_1 + N_2 = W_b + W_p \text{ (equation 1)}$$

There are two general types of motion caused by forces acting on an object. The first, called "*translational motion*," is the kind of "straight" motion discussed in the example of the system falling downward under its weight if it were not balanced by upward forces. The second kind of motion that could result from these same forces is called "*rotational motion*." Imagine that the left chair was removed. The left end of the board with the person on it would swing downward

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in an arc toward the floor. In other words, it would rotate in a counterclockwise direction. *The rotational effectiveness of a force is equal to the amount of force multiplied by the distance from the line of action of the force to the axis of rotation you are considering.* This product is called *torque*, and its direction is either clockwise or counterclockwise. Figure 2 shows the torques acting on the system, with "A" as the axis of rotation. Think of the board and person as the hand on a clock. W_b and W_p would tend to turn the "hand" counterclockwise. The force N_1 would tend to turn it clockwise, and the force N_2 would have no rotational effect because it passes through the axis of rotation. Remember that both W_b and W_p have lines of action through their centers of gravity. The center of gravity of the board is its geometrical center because it is a uniform rectangular solid. The position of the center of gravity of the person is what we are trying to determine and will be defined by X, the distance from A, the axis we have chosen.

Torque = force × distance from axis
A = axis of rotation

Counterclockwise torques
$W_b \times L/2$
$W_p \times X$

Clockwise torques
$N_1 \times L$

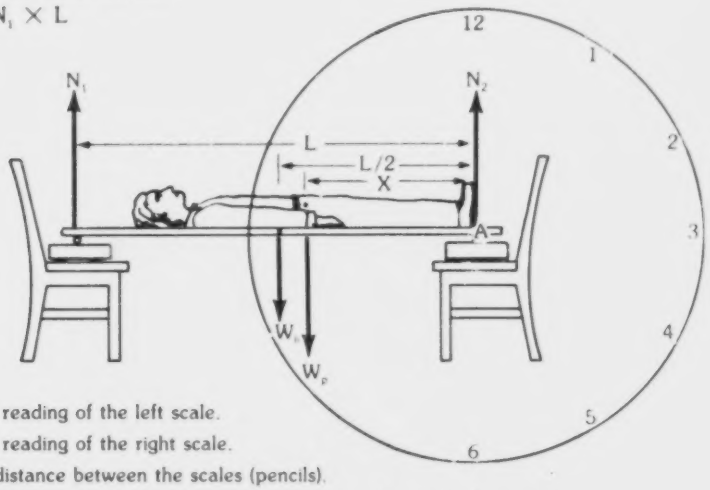

figure 2

N_1 is the reading of the left scale.
N_2 is the reading of the right scale.
L is the distance between the scales (pencils).
X is the distance from the right scale to the person's center of gravity.
W_b is the weight of the board.
W_p is the weight of the person.
A is the axis of rotation.

The second condition of equilibrium is that clockwise torques balance counterclockwise torques. Using the right pencil as the axis of rotation we can write

$$(N_1)L = \frac{(W_b)L}{2} + (W_p)X \quad \text{(equation 2)}$$

From equations 1 and 2 we can solve for X as follows:

To isolate X in equation 2
subtract $(W_b)L/2$ from both sides

$$(N_1)L - \frac{(W_b)L}{2} = (W_p)X$$

and divide by both sides by (W_p)

$$\frac{(N_1)L - (W_b)L/2}{W_p} = X.$$

Now simplify

$$L\left(\frac{N_1 - W_b/2}{W_p}\right) = X.$$

In your recorded data you have values for L, N_1 and W_b. In order to solve for X, you will need to express W_p in these terms. You can use equation 1 to do this. To isolate W_p, subtract W_b from both sides

$$N_1 + N_2 - W_b = W_p$$

Now substitute $N_1 + N_2 - W_b$ for W_p in the equation you derived above

$$L\left(\frac{N_1 - W_b/2}{N_1 + N_2 - W_b}\right) = X.$$

Substitute values from your data sheet and calculate X. Since you placed your feet over the right pencil when you did the experiment, X, the distance from the right pencil to the center of gravity of the body, is also the distance from your feet to your center of gravity when you are standing.

OUR FINDINGS:

See Section V.

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WATER ROCKETS

Daniela Taylor

TOPIC:

Trajectory Analysis

INTRODUCTION:

Missiles and rockets launched at oblique angles belong to a class of moving objects known to physicists as *projectiles*, whose motion is defined by certain known laws. These laws dictate that a projectile's *range*—the total horizontal distance it travels—is partially determined by the angle at which it is launched. In this project, you will test the range of a water rocket at different angles and compare your experimental results with values obtained from equations used by engineers to calculate a rocket's range in advance of firing.

TIME NEEDED:

1 hour

MATERIALS:

1 water rocket with funnel (can be found at a toy store, hobby store or drug store)
container for water
cocktail straw
protractor
meter stick
stopwatch or watch with second hand
graph paper

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Perform the experiment in a large, open outdoor space. Clear the area. Never aim the rocket at anyone. Do not use more than 15 pumps of air, or the rocket seam will split.

PROCEDURE:

1. Bend the rocket's fins at 90° angles away from each other. Set up the rocket on the ground in a large area such as a football field and fill the rocket with water to the full line. If you have trouble filling the rocket with water because of a water barrier formed in the narrow opening, try the following adjustments:
   - angle the rocket slightly while pouring directly into it.
   - jiggle the funnel vigorously up and down in the opening while using very small amounts of water in the funnel at a time.
   - insert a cocktail straw through the opening in the rocket with its end below the full level in the funnel so that it can conduct water through the opening (be careful not to drop the straw into the rocket).

Be sure to fill the rocket to exactly the same level for every trial, or your results will be distorted.

2. Pump the rocket 15 times and release it at 15° to the horizontal. Use a protractor to measure the angle as shown in the illustration. Record time in the air and range (total horizontal distance traveled).

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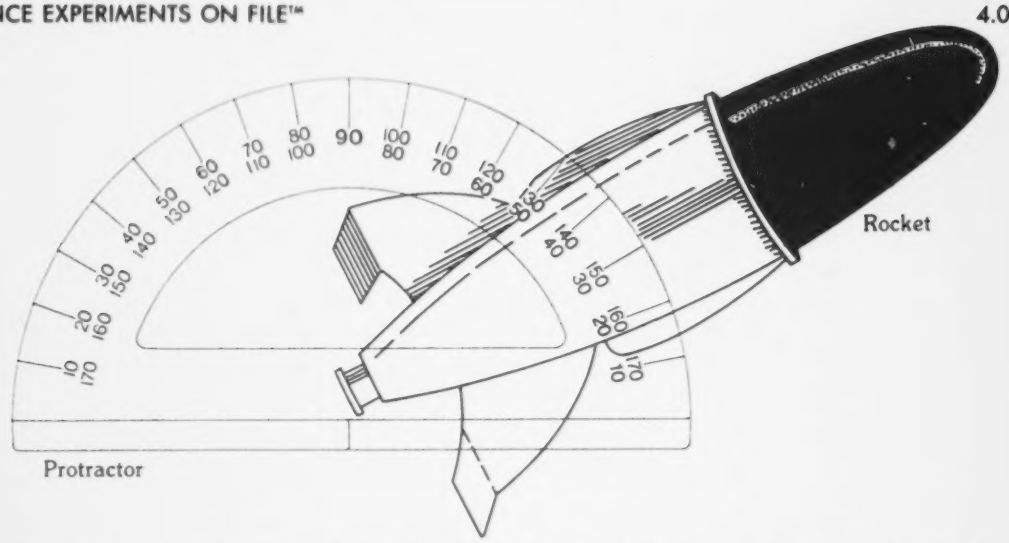

3. Repeat for 30°, 45°, and 60°. When launching at higher angles, lift the rocket slightly off the ground by placing two or three fingers beneath it so that the water's thrust will not be affected by the ground.
4. Fill in Data Table 1.

DATA TABLE 1

Angle of launch	Time of flight	Range (horizontal distance traveled)	Weather conditions
15°			
30°			
45°			
60°			

ANALYSIS:

1. Graph your results, with angles of launch on the X axis and range on the Y axis.
2. In order to calculate the expected range of the rocket for each of your trials and compare your experimental results with the expected results, you will need to use a set of equations given in step 3. The terms used in the equations are defined below, and values are given where they cannot be obtained directly from your Data Table. The units of measurement in which each term should be expressed appear in parentheses.

R = range (meters)
H = height (meters)
T = total time of rocket flight (seconds)
Vv = vertical velocity (meters/second)
Vo = original velocity, that is, speed at which rocket is launched (meters/second)
g = gravitational acceleration = 9.8 meters/second^2
Θ = angle of launch
sin Θ = sine of the angle of launch; sine is a constant trigonometric ratio, the given value of which is determined by the given angle
sin 2Θ = sine of twice the value of the angle of launch, for example sin 2(15°) = sin 30°

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$\therefore$ = therefore
sin 15° = .259
sin 30° = .500
sin 45° = .707
sin 60° = .866
sin 90° = 1.000
sin 120° = cosin (120° − 90°) = cosin 30° = .866

3. Using
$T = 2Vv/g \therefore Vv = Tg/2$ and $Vv = V\text{o}\sin\Theta \therefore V\text{o} = Vv/\sin\Theta$,
mathematically calculate the expected range, $R = V\text{o}^2 \sin 2\Theta/g$ for each angle.
Use Data Table 2 below to record the steps in your calculations so you will be able to check them.

DATA TABLE 2

Angle	T (sec.)	H (meters)	R measured (meters)	R calculated (meters)	Er (%)
15°					
30°					
45°					
60°					

4. To find the percentage error of each of your measurements of range, subtract your experimental result for the range of each trial from the expected range for that angle that you calculated in step 3. Divide the difference by the expected range and multiply by 100 to express as a percentage. The equation is

$$\text{percentage error} = \textit{difference}/\text{expected range} \times 100.$$

5. Calculate the maximum height (H) for each angle of launch using the formula

$$H = Vv(T/2) - \tfrac{1}{2}\, g(T/2)^2.$$

6. Graph your results showing height on the X axis and range on the Y axis.
7. Fill in the results of your analysis on the Data Table.

OUR FINDINGS:

See Section V.

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PROJECTILES AND GRAVITY

David C. Tucker

TOPIC:

Projectile Motion

INTRODUCTION:

An object thrown into motion in any direction other than straight up or down is called a *projectile*. Baseballs, rockets, slingshots, and frisbees all commonly move as projectiles. The curved path traveled by a projectile is called its *trajectory*. The trajectory can be analyzed into separate horizontal and vertical components, which have independent distance and velocity but which act over the same time. In this project, you will employ this characteristic of projectile motion to calculate the trajectory of a ball launched from a track.

TIME NEEDED:

2 hours

MATERIALS:

- steel or glass ball about 1.5 cm in diameter (a marble will work)
- 1 sheet carbon paper
- 1 sheet typing paper
- ring stand with 3-in. ring
- flat table or countertop on which to mount track
- carpenter's level
- metric ruler
- flexible U-shaped corner plastic molding (not rigid v-shaped)—available in 8-ft. lengths at lumber yards and home improvement stores
- masking tape
- plastic pushpins
- picture wire
- plumb bob

Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

1. Set the track up as shown in the figure 1. Puncture one end of the track and attach a loop of wire through it. Stick a pushpin in the wall about 5 feet above the tabletop and hook the wire loop over it so that the track is flush with the wall (see detail of the figure 1). Attach the other end of the track to the table edge with double masking tape beneath it and pieces of supporting tape on the sides. The bottom edge of the track should be right at the table's edge or projecting over it slightly. Use the carpenter's level to make sure that the track is completely horizontal at the point where the ball leaves it. Place a box or a stack of books under the middle of the track and attach with the tape if necessary. The entire track must be securely mounted so it does not wobble when the ball rolls down it.
2. With tape, mark a point near the top of the track from which to start all trials. Practice releasing the ball to avoid "backspin." It is crucial to start from the same spot every time, since it will affect the velocity of the ball at the bottom of the track. Notice about where the ball lands

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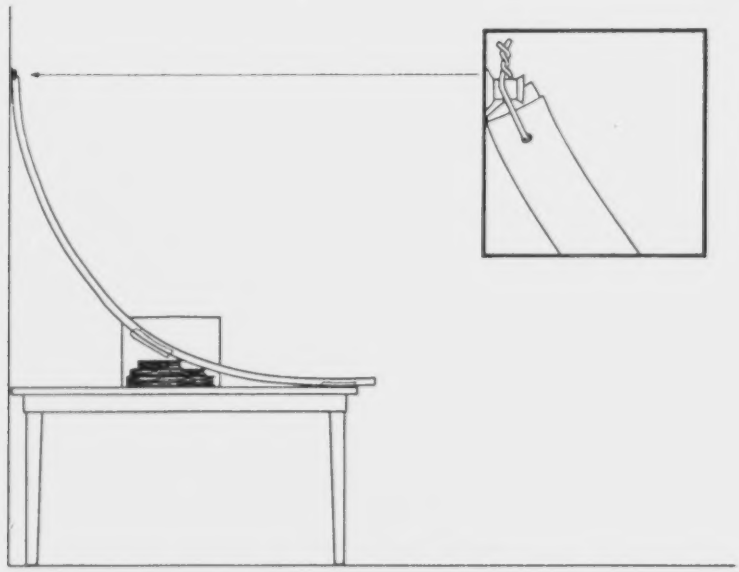
on the floor, and after you are through practicing, tape a piece of white typing paper over the area and then tape a piece of carbon paper face down over it.



Detail: track attached to wall with pushpin and wire loop

figure 1. Track setup

3. Use the plumb bob to mark a spot on the floor directly underneath the end of the bottom of the track. You will use this for later measurements.

4. Roll the ball down the track from the starting position so it hits the floor on the carbon paper-white paper combination to make a spot where it lands. After some practice these spots should be very close together, which indicates good technique and no track wobble.

5. Now you are ready to calculate the trajectory of the ball after it is launched from the track until it hits the floor. As stated in the introduction, projectile motion consists of two independent vertical and horizontal components that occur over the same time. Ignoring air resistance, which is negligible for the smooth, dense ball, the vertical component of the projectile's motion is identical to the motion of an object in free-fall—subject to the constant acceleration of gravity. The horizontal component is uniform—it has constant velocity.

The following equations express this mathematically:

vertical component

$$dv = \tfrac{1}{2}gt^2$$

where

dv = vertical distance traveled by the ball

g = constant acceleration due to gravity = 980 cm/sec^2

t = time it takes for the ball's flight

horizontal component

$$dh = vht$$

where

dh = horizontal distance traveled by the ball

vh = constant velocity at which the ball travels horizontally

t = time it takes for the ball's flight

Note that though the value of dv will be independent of the values for dh and vh, t will have the same value in both equations.

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ANALYSIS:

1. First obtain values for dv and dh by direct measurement:

a. Measure the distance from the center of the spots on the paper to the plumb-bob spot (in cm). This is dh, the horizontal distance traveled by the ball from the end of the track to landing.

b. Measure the height (in cm) from the point where the ball leaves the track to the plumb-bob spot on the floor. This is dv, the vertical distance traveled by the ball from the end of the track to landing.

2. Since g is a constant (980 cm/sec^2), you now have values for two of the three unknown terms in the equation for vertical motion and you can solve for t as follows:

vertical motion

$$dv = \tfrac{1}{2}gt^2$$

multiply both sides by two

$$2dv = gt^2$$

divide both sides by g to isolate t

$$2dv/g = t^2$$

take the square root to remove the square

$$\sqrt{\frac{2dv}{g}} = t$$

substitute known values of dv and g and solve for t

3. Because the horizontal component of projectile motion takes place over the same time as the vertical component, you can use the value of t obtained in the step above to solve for vh as follows:

horizontal motion

$$dh = vht$$

divide both sides by t to isolate vh

$$vh = dh/t$$

substitute known values of dh and t and solve for vh

You now know the values of all the terms in the equations describing the projectile motion of the ball launched from the track. To make sure that your calculations really do accurately describe the ball's motion when it leaves the track, perform the following verification procedure:

1. Set the height of the ring on the ring stand so that its distance from the floor is less than the value of dv (the height of the track from the floor).

2. Using your solutions to the equations for vertical and horizontal motion, you can now determine where to set the ring stand so that the ball will drop through the ring on its path from the track to the ground.

3. In order to set the ring stand correctly, you will need to know the vertical and horizontal distances traveled by the ball from the end of the track to the center of the ring. Look at figure 2 for an illustration of the relationships of these values to the values of dv and dh you have already obtained.

4. To obtain the vertical distance traveled by the ball from the track to the ring (dv_1), subtract the height of the ring from the height of the track (dv).

5. Substitute this new vertical distance value (d_1) in the equation for vertical motion $dv_1 = \tfrac{1}{2}gt_1^2$ to find the new value for t_1, that is, how much time it will take the ball to go from the end of the track to the ring. Now, substitute this new value for t_1 in the equation for horizontal motion: $dh_1 = vht_1$, along with the value for vh you obtained in your initial calculations (remember, vh is

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constant) and solve for dh_1. This is the distance from the plumb-bob spot to the place where you should place the center of the ring.

6. Try it to see if it works. *No practice!* If it doesn't work, don't shift the ring around. Go back over your calculations, starting with your original measurements of dv and dh. Check your arithmetic for errors. Remeasure the height of the ring and check to see that you correctly figured dv_1. Double-check your calculation of vh. Make any needed adjustments to the position of the ring according to your revised calculations. Make sure you are still starting the ball from exactly the same spot on the track. If all the measurements and calculations are in order, this verification procedure will work.

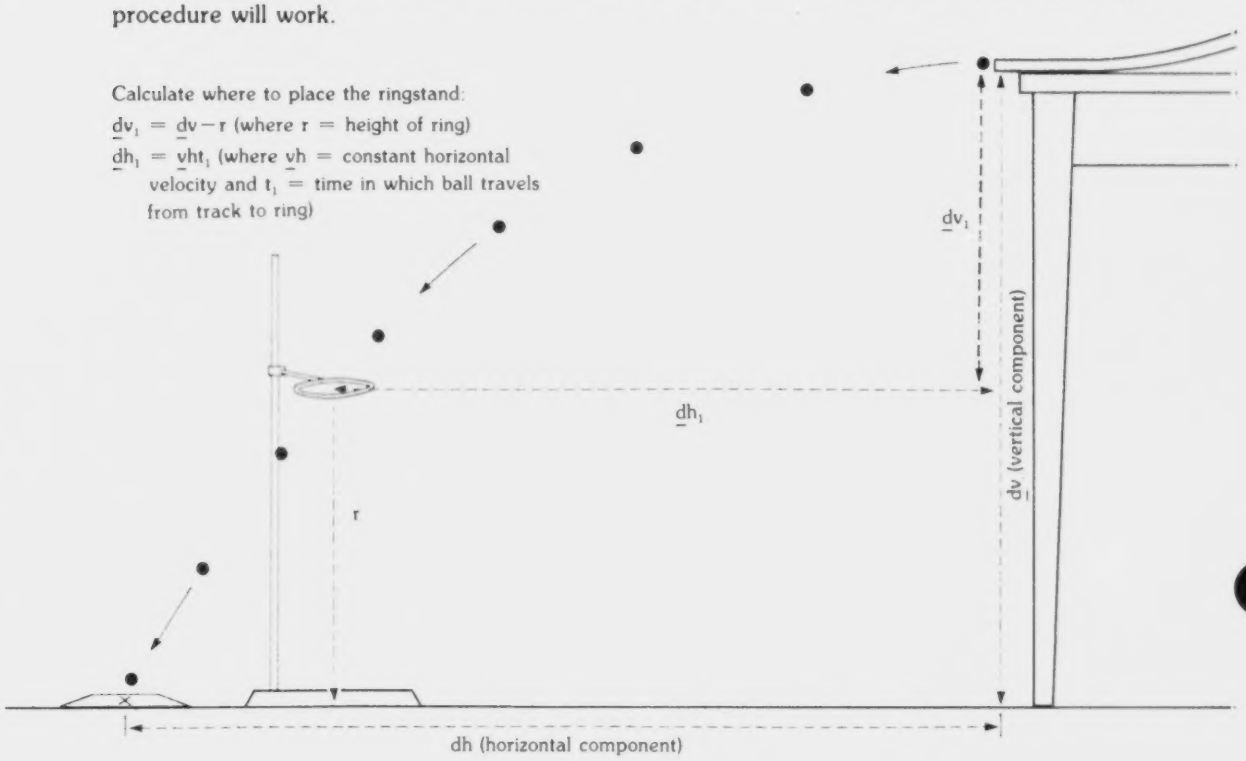
Calculate where to place the ringstand:
$\underline{dv}_1 = \underline{dv} - r$ (where r = height of ring)
$\underline{dh}_1 = \underline{v}ht_1$ (where $\underline{v}h$ = constant horizontal velocity and t_1 = time in which ball travels from track to ring)
$\underline{dv}_1$
$\underline{dh}_1$
r
$\underline{dv}$ (vertical component)
dh (horizontal component)

figure 2

OUR FINDINGS:

See Section V.

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FIGHTING FRICTION

Jeanne Lundquist

TOPIC:

Friction on an Inclined Plane

INTRODUCTION:

Friction is a force caused by surfaces rubbing across one another. It resists motion. In this experiment you will observe the effects of friction and consider ways to reduce it.

HYPOTHESIS:

Friction increases the force necessary to move an object.

TIME NEEDED:

1 hour

MATERIALS:

- metric force gauge or hanging scale (0 to 2000 g)
- roller skate
- cardboard or wooden box (similar in size to skate)
- rocks, blocks, or weights
- board (15 cm × 60-100 cm)
- 2-3 books
- metric ruler

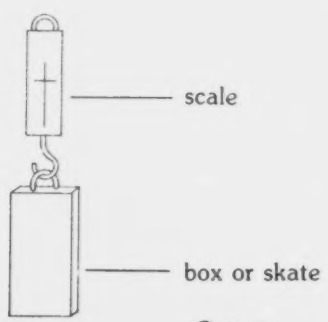
Safety Precautions

Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

1. Lift the skate with the metric scale and read its mass. (See figure 1.) Record the mass on the Data Table.
2. Lift the box with the scale. Add blocks, rocks, or other small objects until it is the same mass as the skate. Record the mass on the Data Table.

figure 1



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3. Set up the inclined plane as shown in figure 2. The length should be about 60-100 cm and the height about 15-20 cm. Fill in the space where the board meets the counter with a piece of cardboard to make a smooth ramp.

4. Measure the height of the inclined plane in meters. Record this figure as H.

5. Place the skate or box on the ramp and draw a line for your starting point. Measure the distance from the line to the upper end of the board in meters. Record the distance, D.

6. Now you are ready to investigate whether using an inclined plane can save you force and work in lifting a box or a skate. First, determine the amount of force required to lift the box or skate without using the inclined plane. (Since the masses are equal, the force required for lifting them will be the same.) To make this calculation, you will use an equation based on Newton's Second Law of Motion, F = ma, or force = mass × acceleration. In this case, the force needed to lift the object = mass of the object × acceleration of gravity g. Assume $g = 10$ meters/sec^2 (acceleration is always expressed in units of distance/time^2). To put your measurements of mass into kilograms you will divide by 1,000. Therefore,

force to lift box or skate = measured mass/1,000 × 10 meters/sec^2.

Calculate and record this number on your Data Table. (For convenience, scientists measure force in units called newtons. One newton (1N) = 1 kilogram × 1 meter/sec^2. Record the number in your Data Table in terms of newtons.)

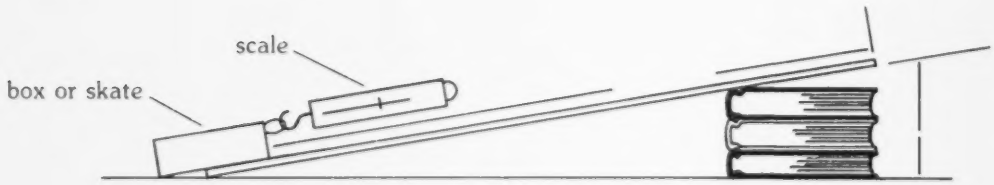
7. For scientists, work is defined as a force causing something to move. The amount of work done is measured by multiplying the size of the force times the distance through which it moves the object; thus work = force × distance. How much work will you do if you lift the box or skate a height equal to H without the inclined plane? Multiply the force needed (in newtons) times the distance (H, in meters) to calculate the work done in newton-meters, called joules, the standard unit of work. Record this figure on the Data Table.

8. Now use the inclined plane to help you do your work. Place the box on the ramp and pull slowly and steadily to the top of the ramp. Read your scale:_____g. Convert this to force as you did in step 6. Record the force required to pull the box on the Data Table.

9. How much work did you do by pulling the box? Multiply the force in step 8 by the distance (D) to find out. Record this figure on the Data Table.

10. Now try pulling the skate up the inclined plane. Start at the same point, pull the skate slowly and steadily to the top, and read the scale:_____g. Convert this to force as in step 6. Record this figure on the Data Table.

11. How much work did you do pulling the skate? Again multiply your force by D. Record this figure on the Data Table.



Distance = D (in meters)
Height = H (in meters)

figure 2

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DATA TABLE

Mass of skate (step 1)	_____ grams
Mass of weighted box (step 2)	_____ grams
H = Height of inclined plane (step 4)	_____ meters
D = Distance of inclined plane (step 5)	_____ meters
Force required to lift box or skate (step 6)	_____ newtons
Work required to lift box or skate to height H without using inclined plane (step 7)	_____ joules
Force required to pull box to top of inclined plane (step 8)	_____ newtons
Work required to pull box to top of inclned plane (step 9)	_____ joules
Force required to pull skate to top of inclined plane (step 10)	_____ newtons
Work required to pull skate to top of inclined plane (step 11)	_____ joules

ANALYSIS:

1. Did pulling the box up the inclined plane require more force or less force than simply lifting it to the same height?
2. If a simple machine (the inclined plane) should change only the force required or the direction of the force, why did you have to do more work pulling the box up the inclined plane than you did just lifting it? (Remember work = force × distance.)
3. Compare your figures for pulling the box and pulling the skate. Can you explain why the work required to pull the skate is so much less than the work to pull the box?
4. Compare your values for the work needed to lift the skate and work needed to pull the skate up the inclined plane. Explain any difference you find.
5. State in your own words how friction affected the result of your experiment with the inclined plane.
6. Think of two or three ways you might be able to reduce friction between the box and the inclined plane. Test your ideas by running the experiment again. Were you able to reduce the amount of work required?

OUR FINDINGS:

See Section V.

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PITCHING SPEED

Arthur Eisenkraft, Ph.D.

TOPIC:

Conservation of Momentum and Energy

INTRODUCTION:

The momentum of a body is the product of its mass and velocity. When a system of bodies undergoes an explosion or collision, individual bodies in the system may experience changes in their momentum, but the total momentum of the system before and after the event will be the same. This principle is known as conservation of momentum. Knowledge of this principle, along with the known laws under which energy is conserved, make it possible to calculate physical quantities—such as velocities—in situations in which they cannot be measured directly. In this project, you will use these principles to calculate your softball-pitching speed.

TIME NEEDED:

1½ hours

MATERIALS:

cardboard box (approximately .5m *x* .5m *x* .5m, but exact size is not important)
softball
string
construction paper
masking tape
meter stick
newspaper
scissors
ladder or step stool
slide projector, large flashlight, or desk lamp
triple beam balance scale, hanging scale, or food scale

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Be careful when climbing the ladder. Make sure everyone is out of the range of the softball when you are throwing it and clear the area of anything that could be damaged by the swinging box or a stray ball.

PROCEDURE:

1. Choose a partner for this experiment.
2. Cut a large square hole in one side of the cardboard box. Almost the entire side of the box should be removed. Using construction paper and masking tape, make a "door" in the opening so that two pieces of paper overlap approximately ½ inch at the center of the opening. This will prevent the ball from falling out of the box (see figure 1).

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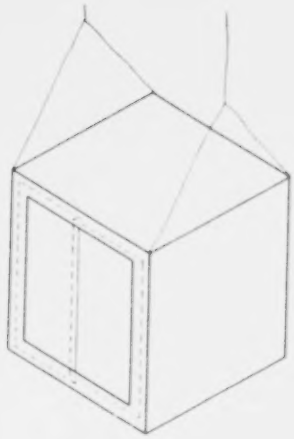


figure 1

3. Fill the box with crumpled newspaper.

4. Attach string as shown in figure 1. The string should be long enough to suspend the box to strike-zone height. Turn the box over. Using the meter stick, draw two diagonals to locate the center of the box and mark it.

5. Use the scale to measure the mass of the box filled with newspaper. Convert the mass to grams if necessary and record this figure as M on the Data Table.

DATA TABLE

h_1 (starting height of box)	
h_2 (height after hit)	
Δh ($h_2 - h_1$)	
M (mass of box)	
m (mass of ball)	

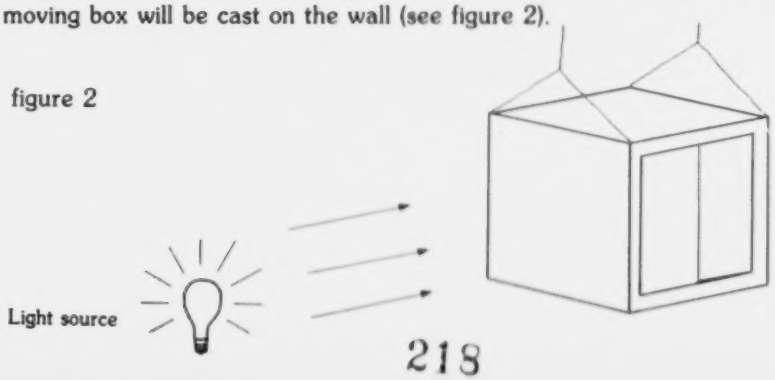
6. Measure the mass of the ball and record this figure on the Data Table.

7. Choose a garage or a safe outdoor location for the experiment where there is a place to suspend the cardboard box by strings (e.g., a garage ceiling beam or tree branch). There must be a wall nearby on which the box will cast a shadow. If you are doing the experiment outside, choose a cloudy day.

8. Suspend the box by the strings, with the hole facing the direction from which you will throw the ball. The box should be at strike-zone height and should be able to swing freely when hit by the softball. Clear the area of anything that could be damaged by the swinging box or a stray ball.

9. Set up the slide projector, flashlight, or lamp in such a location that the shadow of the side of the moving box will be cast on the wall (see figure 2).

figure 2



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10. Have your partner standing nearby to observe the shadow of the box as it swings. The partner must be able to mark the highest point reached by the bottom front edge of the box on its first swing.

11. Throw the softball into the box. As the box undergoes its first swing, have your partner observe the farthest distance the shadow on the wall moves and then draw a line on the wall to indicate the position of the bottom front edge at that point (see figure 3). Practice throwing the ball into the box. You can stand at whatever distance is most comfortable for you. Try to throw the ball so that it goes through the center of the "door" and hits the back of the box as squarely as possible. This will result in a good, sharp swing with minimal rotation and make it easier to take accurate measurements.

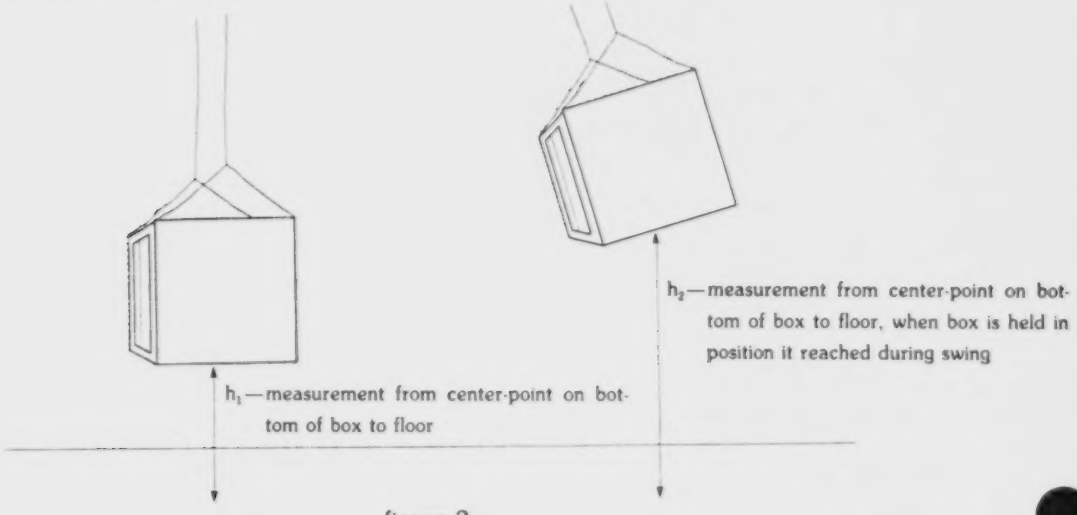
h_2—measurement from center-point on bottom of box to floor, when box is held in position it reached during swing
h_1—measurement from center-point on bottom of box to floor

figure 3

12. Allow the box to hang in its original position. Using the meter stick, measure the distance from the floor to the center of the bottom of the box. Record this figure as h_1 on the Data Table. Now pull the box to the position it reached at the height of its first swing. Measure the distance from the floor to the center of the bottom of the box in this position (see figure 3). Record this figure as h_2. Subtract h_1 from h_2 to determine the change in height (Δh). Record this figure on the Data Table.

ANALYSIS:

When the softball strikes the back of the box, momentum in the ball-box system is conserved. The appropriate equation is:

$$mv = (M + m)V \quad \text{(equation 1)}$$

where
m = mass of the ball
v = velocity of the ball
M = mass of the box
V = velocity of the box with the ball inside.

You have measured the masses of the ball and box, so you have values for m and M. In order to solve equation 1 for v, the ball's velocity, you will need to know the value of V—the velocity of the box after it is struck by the ball. To obtain this, you can use standard equations for two other physical quantities: kinetic energy and gravitational potential energy.

Kinetic energy (KE), is defined as the work an object is capable of doing by virtue of its motion. The equation for kinetic energy is $KE = \frac{1}{2}mv^2$, where m = mass of the object and v = velocity of the object.

Gravitational potential energy (PE) is defined as the work an object is capable of doing by virtue of its position relative to the earth. Its equation is PE = mgh, where m = mass of the object, g = acceleration of gravity (980 cm/s²), and h = the object's height above a given reference point (often the ground).

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The important principle of physics that allows you to manipulate these energy equations to find the velocity of the box with the ball inside is the *conservation of energy*. That is, at any point the total energy in the system will be the same. Therefore, any change in KE will be balanced by a change in PE. The appropriate equation is $\Delta KE = \Delta PE$.

After the moment of impact, the box with the ball inside has both KE (it is moving) and PE (determined by its height from the ground). At the moment at which the box has reached the top of its upward swing, it has zero velocity and thus zero KE. At this point all of its energy is in the form of PE (its height has increased). According to the principle of the conservation of energy, total energy at the two points must be the same, so we can write

$$\tfrac{1}{2}(M + m)V^2 + (M + m)gh_1 = 0 + (M + m)gh_2.$$

To simplify:

$$\begin{aligned}\tfrac{1}{2}(M + m)V^2 &= (M + m)gh_2 - (M + m)gh_1\\ &= (M + m)gh_2 - gh_1\\ &= (M + m)g(h_2 - h_1)\\ \tfrac{1}{2}(M + m)V^2 &= (M + m)g\Delta h.\end{aligned}$$

To further simplify and isolate V, cancel the quantity (M +m), which appears on both sides to get

$$\tfrac{1}{2}V^2 = g\Delta h. \quad \text{(equation 2)}$$

Multiply both sides by 2

$$V^2 = 2g\Delta h$$

and take the square root of both sides

$$V = \sqrt{2g\Delta h}.$$

By substituting the value of V into equation 1 and solving for v, the velocity of the ball can be determined:

$$v = \frac{(M + m)\sqrt{2g\Delta h}}{m} \quad \text{(equation 3)}$$

1. Substitute your measurements into equation 3 and solve for v, the velocity of the ball. Be sure that your units are consistent, that is, that all masses are in grams, distance is in centimeters, and the acceleration due to gravity is given as 980 cm/s^2.
2. The speed of the ball will be in centimeters/second. To compare your pitching speed with professional ball players', you can convert the experimental value into miles/hour. There are 30.5 centimeters in a foot and 5,280 feet in a mile. There are 3,600 (60 x 60) seconds in an hour. To convert to miles/hour, first divide your value in centimeters by 30.5 to convert to feet/second. Then, multiply by 3 600 to get feet/hour. Finally, divide by 5,280 to get miles/hour.

OUR FINDINGS:

See Section V.

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BEHAVIOR OF THE SIMPLE PENDULUM

Carl C. Duzen

TOPIC:

The Behavior of the Simple Pendulum

INTRODUCTION:

Galileo is supposed to have been fascinated by the motion of a chandelier hanging in a cathedral. His observations led him to conclude that the time it takes for a pendulum to make a complete swing does not depend on how wide a swing it makes. In other words, the period (time it takes for one complete swing) is independent of the amplitude (size of the swing). Galileo's observations apply to small amplitudes. In this experiment you will examine the behavior of a simple pendulum and test Galileo's conclusion.

HYPOTHESIS:

When the amplitude is small, the period of a pendulum's swing is dependent on length but not on mass or specific amplitude.

TIME NEEDED:

15 minutes for preparation
40 minutes to completion

MATERIALS:

35-mm film canister with cap (plastic)
stick pin
wood block
heavy thread
sand
apparatus from which to hang pendulum (a coat hook will do if pendulum can swing freely)
protractor
watch with a second hand

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Use caution while piercing the hole in the film canister cap.

PROCEDURE:

1. Assemble the pendulum as follows: Remove the plastic cap from the film canister. Place it on the wood block. Carefully pierce the center of the cap using the stick pin.
2. Put one end of a 60 cm (2 ft.) length of thread through the top of the cap. Tie a knot in the thread on the bottom of the cap so that it cannot be pulled out of the cap.
3. Fill the canister ⅓ full of sand and replace the cap with the thread through it.
4. Attach the pendulum to the apparatus you have chosen to hold it. Make sure that the canister can swing freely. Measure and carefully record the length of the string from contact with apparatus to canister.

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5. Start the pendulum swinging through an arc of between 10°-15°, as measured from the vertical with your protractor. As you let go of the canister, carefully record the time on your watch.

DATA TABLE

	ORIGINAL SETUP (length =)	AMPLITUDE CHANGE	LENGTH CHANGE (length =)	MASS CHANGE
TRIAL 1				
TRIAL 2				
TRIAL 3				
TRIAL 4				
TRIAL 5				
AVERAGE				

6. Count through 20 complete swings of the pendulum and then again carefully record the time. (You take 20 swings because the time for one swing is too small to measure reliably.) Subtract the starting time from the final time to obtain the time it took for 20 complete swings. Record this time in the first box of the Data Table opposite "Trial 1."

7. Repeat this measurement 4 more times, each time recording on the Data Table the time it takes for 20 complete swings.

figure 1

8. Take the average of the 5 trials. This will be the time you compare with times that result from changes in the experimental setup.

9. Do steps 5-8 again but increase the amplitude of the swing by starting it from an angle of between 20°-25°. Compare the average time for 20 swings with the two different amplitudes.

10. Do steps 5-8 again with the original amplitude, but this time lengthen the string by 15 cm (6 in.). Measure and record the new length of the pendulum. Compare the average time for 20 swings with the two different pendulum lengths.

11. Using the original amplitude and string length, do steps 5-8 again, but this time fill the canister ⅔ full of sand. Compare the average time for 20 swings with the two different masses. You have now tested differences in amplitude, pendulum length, and mass.

ANALYSIS:

What conclusions can you come to concerning the effects of the changes in amplitude, pendulum length, and mass on the period of the pendulum?

OUR FINDINGS:

See Section V.

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CLOCKING SPEEDY SOUND WAVES

Linda J. Kanipe

TOPIC:

Speed of Sound in Air

INTRODUCTION:

Sound moves through air the way a ripple moves through water. When an object vibrates back and forth it pushes on the air molecules around it, alternately compressing and releasing them. The disturbed particles bump into other particles that disturb still further particles, creating a sound wave that travels through the air. Sound waves travel at different speeds in different substances and under various conditions. In this project, you will measure the speed of sound in air.

TIME NEEDED:

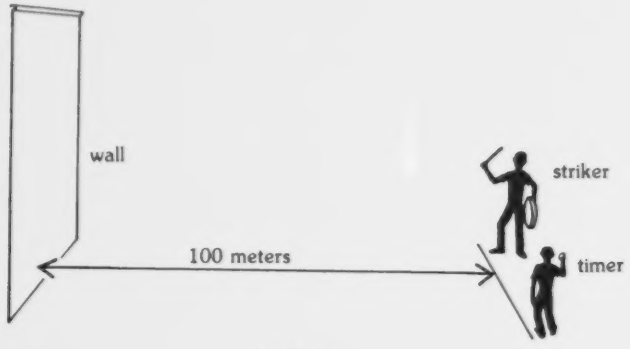
1 hour

MATERIALS:

meter stick or tape measure
Celsius thermometer
stopwatch
drum with stick or aluminum pan and ladle

PROCEDURE:

1. Choose a partner to help you with this experiment.
2. Go outside and measure a distance, as unobstructed as possible, of at least 100 meters from the wall of a building or some other large, flat, vertical surface. Record this distance, and remain at this distance to perform the experiment. If you cannot find a wall with this much unobstructed space in front of it, you can perform a variation of the experiment using a large open field (see Variation, below). However a wall is preferable.
3. Hold the drum or aluminum pan so that the surface to be struck faces the wall from which you just measured the 100 meters (see illustration). Have your partner prepare to operate the stopwatch.



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4. Strike the drum, AND AT THE SAME INSTANT THAT THE DRUM IS STRUCK, have your partner start the stopwatch.
5. Have your partner listen for the echo of the sound from the wall of the building. When this echo is heard, your partner should IMMEDIATELY STOP THE STOPWATCH. Practice this procedure several times. It may help to synchronize striker and timer if the striker calls out a countdown— "three . . . two . . . one" before striking. Then begin to record the elapsed times.
6. Repeat this echo timing about 20 to 30 times. The average value of the recorded times will be used in calculations.

NOTE: Because human reaction time is unreliable, these measurements will form a major source of error. You and your partner should take turns being the timer. Also, results are not as satisfactory on gusty or windy days, since the sound is carried off by the moving air.

7. Record the temperature of the air using the Celsius thermometer.

Variation: This experiment can also be performed on an open field, measuring off the maximum distance available. The greater the distance the better, limited only by the timer's ability to see the striker. In this variation, timer and striker stand at opposite ends of the field. The timing should begin when the timer sees the striker hit the object and should end as the timer hears the sound produced. Then, follow steps 6 and 7 above. In analyzing your data, follow the steps outlined below, except, since an echo is not being measured, the distance between timer and striker is used directly, without doubling.

ANALYSIS:

1. Average the values of time you recorded, after first discarding those values that seem obviously much too high or too low due to human error/reaction time. This average time will be used in the working equation.
2. Using the working equation:

$$\text{speed of sound} = \frac{\text{distance traveled}}{\text{average time}}$$

calculate the speed of sound in air. Remember, since the echo time was measured, the sound produced traveled to the wall and back. Therefore, the distance traveled by the sound equals twice the distance measured from the wall.

3. The accepted value for the speed of sound in air is 331.5 meters/second at 0 °C plus 0.6 meters/second for each degree Celsius above 0 °C. Using this information, calculate the accepted value for the speed of sound at the temperature that you measured and recorded during the experiment.
4. To calculate the percentage of error in your experiment, first take the difference between the speed of sound you calculated (the answer in step 2 above) and the accepted speed of sound at that temperature. Then use the following equation:

$$\text{percentage error} = \frac{\text{amount of error}}{\text{accepted value}} \times 100$$

5. Describe how you could adapt this experiment to calculate the striker's distance from the wall (or the distance between striker and timer in *Variation*), given an accepted speed of sound. Try your experiment and see how close you come to the actual distance.

OUR FINDINGS:

See Section V.

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GARDEN HOSE BUGLE

Donald A. Schaefer
developed by Matthew Brand

TOPIC:

The Physical Basis of the Western Musical Scale

INTRODUCTION:

Sound is the term we use for vibrations in a medium (most often air) and for our perceptions of those vibrations. When an object vibrates in air, it moves back and forth, first pushing air molecules ahead of it closer together, and then, when it moves back, leaving a space with air molecules farther apart. The sound *wave* is actually the disturbance itself that moves away from the source as air molecules bump into adjacent air molecules and transfer the extra energy and momentum they gained from the vibrating source. The waves, consisting of areas of compression (molecules closer together) and rarefaction (molecules farther apart), move out in all directions from the vibrating source in much the same way that waves move away from a spot where a stone is thrown into a pond. When these regions of high and low pressure (compressions and rarefactions) reach our ears, they cause our eardrums to vibrate at the same rate as the original vibration. *Wavelength* is the distance between successive areas of compression in the sound wave. *Frequency* is the rate of vibration—the number of back-and-forth motions, or cycles, a vibrating object makes in one second. The velocity of sound is always equal to the frequency times the wavelength ($V = f\lambda$). *Pitch* is the musical term used to describe our perceptions of sound at different frequencies. When an object vibrates rapidly, it produces sound waves of a high frequency, which we perceive as a high pitched sound. A low frequency vibration is perceived as a low pitch. In this project, you will explore the relationships between the length of the vibrating air column in a garden-hose "bugle," the frequencies of sound it produces, and the pitches that are perceived.

TIME NEEDED:

1 hour

MATERIALS:

1 trumpet, trombone, euphonium or tuba mouthpiece. (See if you can obtain a used mouthpiece from your school's music department. Wash the mouthpiece thoroughly and soak it in alcohol so it does not transfer germs.)
5 m (16-ft) garden hose, about 1 in. outside diameter. (Standard hose designations are ⅝ and ⅞ in. Either is alright, so long as the mouthpiece fits snugly in an end.)
1 funnel to fit snugly in hose end
1 garden shears or utility knife
rubbing alcohol
masking tape
felt-tipped pen
graph paper
musical instrument on which notes can be played and identified, such as a piano or small electronic keyboard

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. If more than one person will be using the apparatus, which will involve breathing into a tube, care should be taken to prevent spreading colds, i.e., wash the mouthpiece.

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PROCEDURE:

It is best to perform this experiment with a partner or in a small group. The experiment makes a great deal of loud noise, so perform it in a place where you will not disturb others. If you are doing it in school, you may have to do it without the funnel to reduce noise.

In a bugle, as in all brass instruments (like the trombone, French horn, euphonium or tuba), the source of vibration is the lips of the player, while in other instruments the source may be a vibrating reed or the air itself. In a piano, violin or guitar, the source is a vibrating string. In every case, these vibrating sources alone do not cause enough air to move to produce a loud sound, so something is caused to vibrate in sympathy with the original source of vibration in order to increase the loudness of the resulting sound. [In the bugle, this is a column of air, which greatly increases the amplitude of the motion of the air molecules carrying the sound away from the tube, and thus the loudness.] Only if the wavelength of the sound is related in a specific way to the length of the air column, will the vibrations reinforce as they travel back and forth in the bugle itself. There must be what is known as a standing wave for this to occur, and this depends upon the velocity of sound in air and the length of the air column (the horn length).

1. If a member ot your experiment group has played a brass instrument before, he or she is the logical choice to produce the sounds with the mouthpiece. Otherwise, have someone from the music department show you how to make it sound. The person who will be doing this should practice with the mouthpiece to gain some control over the pitch of sounds you can make with it. (If different members wish to try making notes, remember to clean the mouthpiece thoroughly and soak it in alcohol each time before the next person uses it.)

2. Cut a length of hose 0.6 m long, and, using the tape and marking pen, label this hose length "1." Fit the mouthpiece snugly in one end and the funnel in the other as shown in figure 1. Try

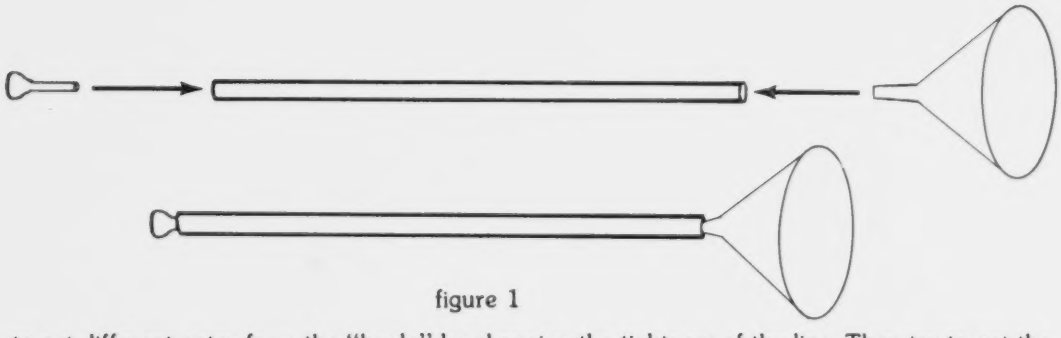

figure 1

to get different notes from the "bugle" by changing the tightness of the lips. Then try to get the lowest pitched clear note possible. Identify this note by playing the reference instrument and finding the note(s) that correspond to the sound coming from the bugle. Record this information on the Data Table as the fundamental resonant frequency note (FRFN) of the #1 (60 cm) horn.

3. Next, try to produce the next two higher pitched notes and identify them by matching their sound with notes produced on the reference instrument. Record these notes on the Data Table as the second and third harmonics.

4. Plot your data on a graph with 2 or 3 octaves of notes identified with half-intervals (semitones) marked off along the horizontal axis and horn length in cm on the vertical axis. Plot the range of notes on the graph that most nearly matched the lowest note your bugle produced and make a dot in the center of this range, which should be the best estimate of the fundamental resonant frequency for your 60-cm bugle. (See the sample graph in figure 2.) The musical scale that uses half-intervals or semitones, as on your reference instrument, is the Western, or equally tempered chromatic scale, and each note's frequency is 1.06 times the frequency of the preceding notes. This produces a note with twice the frequency of any given note 12 notes below it. For example, C above middle C is one octave above middle C, has a frequency twice that of middle C, and is 12 semitones above middle C. On a piano, each key produces a note one semitone higher than the note below it. The black key that follows the white key for middle C is referred to as either C sharp or D flat, and the frequency is 1.06 times that of middle C.

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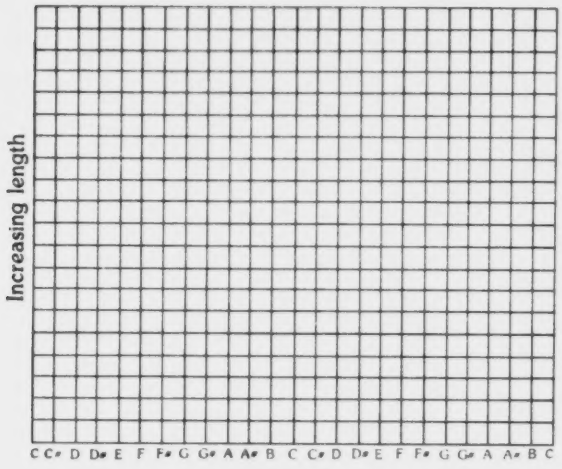

Horn pitch versus horn length

figure 2

5. With the remaining length of hose, cut lengths that are 4/5, 3/4 and 2/3 of the length (60 cm) of your original bugle. Label the new horns according to these fractions. Transfer the mouthpiece to each of these lengths in turn and find the fundamental resonant (lowest) frequency

DATA TABLE

Horn no.	L—Horn length in cm	Note(s) identified by ref. instrmt.	f—Frequency in vibrations/second	λ—Wavelength in cm
1		FRFN		
1		Second harmonic		
1		Third harmonic		
4/5		FRFN		
3/4		FRFN		
2/3		FRFN		
5/4		FRFN		
4/3		FRFN		
3/2		FRFN		

FRFN = Fundamental Resonant Frequency Note

for each length horn. Record these notes on the Data Table opposite the horn numbers (fractions) and their lengths. Plot the data on your graph along with the data from your original horn. Cut and label lengths that are 5/4, 4/3 and 3/2 of the first length. Find, record and plot their fundamental resonant frequencies as well.

ANALYSIS:

Note: Because this experiment uses relatively crude measurements and tries to match pitches with those that are not precisely the same, and because of different mouthpieces and abilities to produce pure notes, the data actually obtained in this experiment will not exactly replicate data obtained under more accurately controlled circumstances. However, results within 1 or 2

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half-intervals often result.

1. As the hose gets longer, what happens to the pitch? As it gets shorter, what happens? Can you make a general statement that relates the length of the resonating air column in the horn, the fundamental frequency as identified by the reference instrument and the pitch? What is the main effect when the funnel is inserted into the opposite end of the hose from the mouthpiece?
2. Referring to the formula that relates velocity (V), frequency (f) and wavelength (λ)of sound ($V = f\lambda$), and assuming that the velocity of sound at room temperature is about 345 meters/second, can you calculate the wavelength (λ) of each of the notes you have identified? (Assume that the frequency of the note middle C is about 260 vibrations/second, and remember that each note is 1.06 × the frequency of the preceding note one semitone below it.) Write the frequency and wavelength next to each note on the Data Table. Based on this frequency data and your graph, can you state a relationship between the lengths of the air columns of the horns and their fundamental resonant frequencies? If your graph is not a straight line, what could you plot that you believe would result in a straight line graph? Can you write a mathematical equation that represents this relation?
3. Try to determine the mathematical relation between the wavelength (in cm) of a horn's fundamental resonant frequency note and the length of the air column (also in cm) that produces it. Remember the uncertainties in your data as you search for these specific relationships.
4. Look at your data identifying the second and third harmonics of the first horn. Can you notice any relationship between the frequencies of these notes and the fundamental resonant frequency of the horn that produces them?
5. Compare the number of semitones between the pitch of the fundamental frequency of the 5/4 horn and the original (60-cm) horn and between the original horn and the 4/5 horn. Is there any regularity? Do the same for the 4/3 horn, the original horn and the 3/4 horn and then for the 3/2, original, and 2/3 horns? Is there any regularity?
6. The 3/2 horn is twice the length of the 3/4 horn (The 3/2 horn is 90 cm long and the 3/4 horn 45 cm). What would you predict the frequency relation would be for the fundamental for each of these lengths? What would their pitch relation be? What does the data show? Within the limits of experimental uncertainty, does your data verify this prediction?
7. Considering your conclusions relating air column length to frequency and pitch of produced sounds, how would you go about designing a complete set of horns that would play every note on the piano?

OUR FINDINGS:

See Section V.

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ROY G. BIV

Dr. Charles W. McLaughlin

TOPIC:

Relationship between Wavelength and Frequency of Light

INTRODUCTION:

The "white" light from the sun is actually composed of the colors red, orange, yellow, green, blue, indigo, and violet, which become visible when sunlight passes through a prism. The colors always appear in this order; a good way to remember the order is to note that the first letters of the colors spell out the name ROY G. BIV. We can think of light as traveling in waves with properties of *wavelength* and *frequency*. Wavelength is the distance between identical locations on adjacent waves (see figure 1).

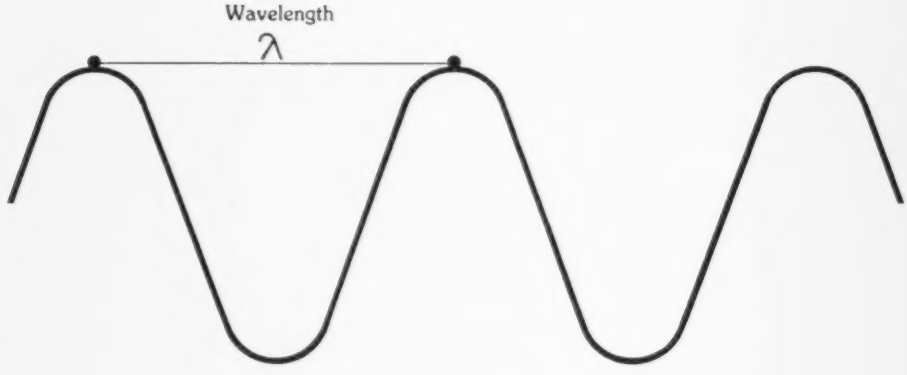

figure 1

Frequency is the number of complete waves (or wavelengths) that pass a given point each second. All light travels at the same velocity, but each color has a different wavelength and frequency. It is their different wavelengths that cause the different colors of light to separate and become visible when passing through a prism. Red light has the longest wavelength. The wavelengths of the other colors decrease in order, with violet light having the shortest. In this project you will construct a simplified model of different light waves in order to identify a constant relationship between wavelength and frequency.

TIME NEEDED:

1 hour

MATERIALS:

roll of adding machine tape
red, blue, and green colored pencils
yardstick or ruler
cardboard about 8 in. square
scissors
6 books
stopwatch

PROCEDURE:

You will need an assistant for part of the procedure.

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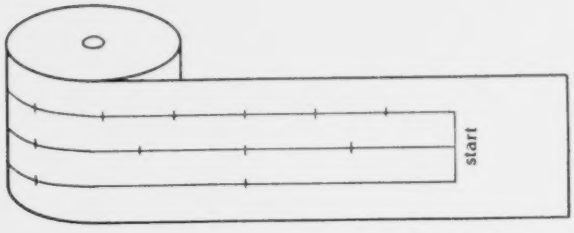
1. Draw a vertical line about 6 in. from the beginning of the adding machine tape and label it "Start" (see figure 2). With the yardstick, mark a point 60 in. from the starting point. Draw a vertical line and label it "End." Do not cut the marked portion of the tape off the roll.



Top line is blue, marked every 2 inches. Middle line is green, marked every 3 inches. Bottom line is red, marked every 6 inches.

figure 2

2. Using colored pencils, draw 3 evenly spaced horizontal lines along the tape from Start to End. Make the top line blue, the middle line green, and the bottom line red to represent three different colors in the spectrum of light.

3. Divide the red line every 6 in. with clearly visible vertical marks in red pencil. Divide the green line every 3 in. and the blue line every 2 in. The marks at different intervals on the 3 lines represent the different "wavelengths" of the different colors of light. (The difference between wavelengths of actual blue, green, and red light waves is proportionately smaller than in your model, but their relationship is the same: red has the longest wavelength, green is shorter, and blue shorter still.

4. Wind the marked tape back onto the spool and insert a pencil through the middle of the spool.

5. Cut a rectangular opening in the middle of the cardboard about 3 in. high and 1½ in. wide as shown in figure 3.

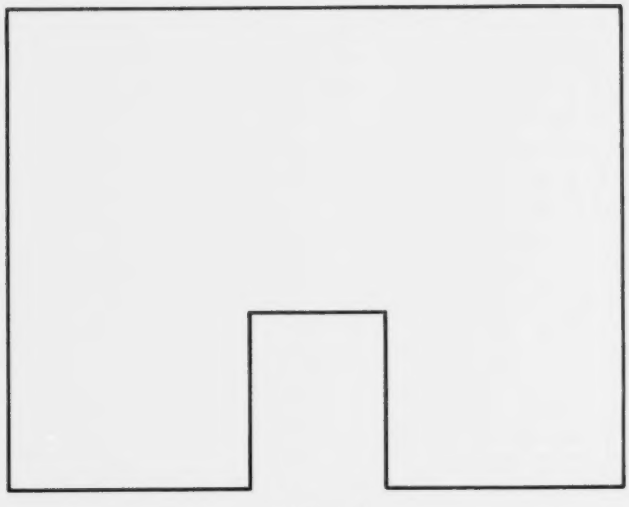


figure 3

6. Set the cardboard on the table, supporting it with books. (See figure 4.) Feed the end of the adding machine tape through the narrow space between the cardboard and the back pile of books until "Start" appears in the middle of the opening in the cardboard.

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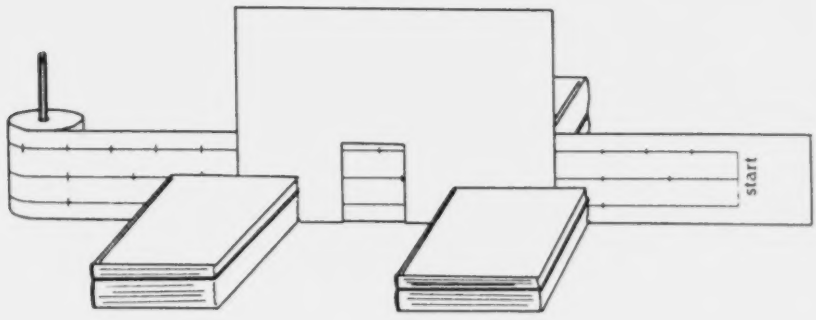

figure 4

7. Divide a sheet of paper into 3 vertical columns and label them red, green and blue.
8. Sit in a chair at the table in front of the cardboard door and tape apparatus. Have your assistant call "start" and begin timing as he or she slowly pulls the tape along. Each time you see a wavelength mark put a dash in the box of that color on the data sheet. When the vertical "End" line appears in the door, tell your assistant to stop timing.
9. Repeat the procedure several times, until you get consistent results.

ANALYSIS:

1. On the Data Table, record the average number of wavelengths observed for each color and the average time of the trials.
2. Since frequency is defined as the number of wavelengths passing a given point per second, determine the frequency for each of your colored lightwaves and record the results in the frequency column.

DATA TABLE

Color	Wavelength	Avg. No. of Wavelengths Observed	Time	Frequency
Red	6 inches			
Green	3 inches			
Blue	2 inches			

3. Compare the wavelengths and frequencies of the three waves. Do you notice any pattern in their relationship? What is the mathematical relationship of the red wavelength to the green? To the blue? What is the relationship of the red frequency to the green frequency? To the blue? Which wave has the highest frequency? The longest wavelength? Which has the shortest wavelength? The lowest frequency?

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4. From your answers to the questions above, can you deduce a constant relationship between wavelength and frequency in waves that travel at the same velocity like the ones represented on the paper strip?
5. Using what you now know about the relationship between time, distance, and velocity, what is the velocity of the waves?
6. Multiply the wavelength of the red wave by its frequency. Do this for the blue and green waves also. What do you notice about the results?
7. Write a constant formula for the velocity of waves in terms of wavelength and frequency instead of distance and time.

OUR FINDINGS:

See Section V.

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IMAGES FORMED BY PLANE MIRRORS

Donald A. Schaefer

TOPIC:

Laws of Reflection

INTRODUCTION:

Optical laws of reflection underlie the design and operation of optical instruments, including cameras, microscopes, and telescopes. In this project you will investigate the laws governing reflection in plane (flat) mirrors.

TIME NEEDED:

1 hour

MATERIALS:

- 2 sheets Plexiglas, each about 1 foot square
- 4 heavy bookends
- 2 identical candles
- 2 identical candleholders
- ruler
- 1 string of multicolored Christmas-tree lights
- tape

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Do not use glass.

PROCEDURE:

Part A: Reflection in a Single Plane Mirror

1. Using two of the bookends, stand a sheet of Plexiglas up on its side in the middle of a table, with two bookends on one corner holding it vertical as shown in figure 1. Light one of the candles and place it in front of the sheet. This is the "object" candle. Dim the lights. Look through the Plexiglas sheet to the place where the candle appears to be and place a second candle there. Notice that your "image" candle appears to be lighted, even though it is not. Light the second candle.

2. Stay on the object candle side of the mirror. Move to your left and then to your right while looking at the reflected image of the first candle superimposed on the second candle. Notice that the image itself disappears when you move too far left or right. Does the second candle always seem to be perfectly aligned with the reflected image of the first candle?

3. Measure the distance from the object candle to the Plexiglas. To which surface of the Plexiglas should you measure? Why that surface? Try bringing your pencil up next to the mirror surface. Does your pencil top seem to touch its image or is there a small space between them? What does this observation tell you? Measure the distance from the image candle to the Plexiglas. Record your measurements D_o (object distance) and D_i (image distance) on the Data Table.

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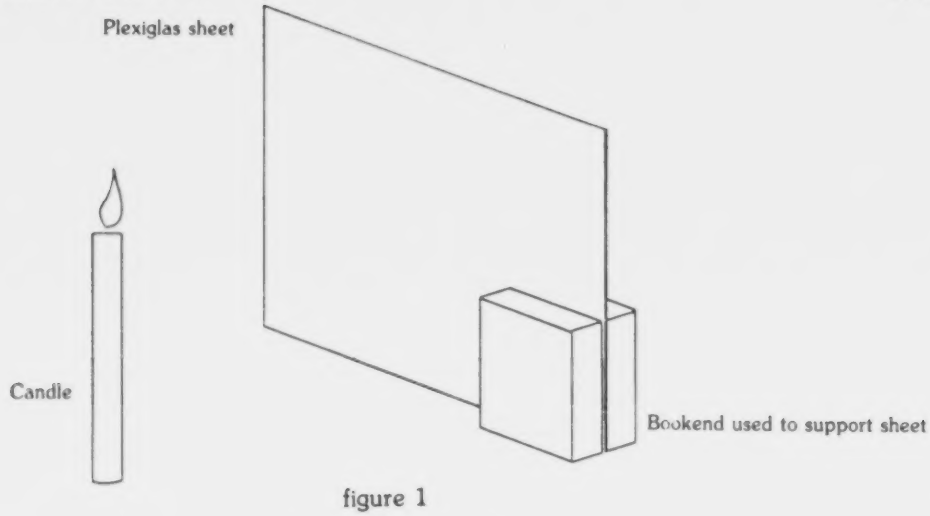

figure 1

DATA TABLE

Single mirror		
Position	D_o	D_i
Position 1		
Position 2		

	Double mirrors		
	Angle	D_o	D_i (Record D_i for each image seen)
	90°		
Angles you chose less than 90°			

4. Move the object candle closer to the sheet and adjust the image candle so it again appears to be perfectly aligned with the image, even when you move from left to right. Repeat steps 2 and 3. Can you conclude that there is a definite relationship between D_o and D_i values? Draw a diagram of the mirror, the candle, the reflected image, and where your eye is located when you make observations for one particular object/image arrangement. Draw 3 "lines of sight" in your diagram that show the path the light took from the image to the mirror to your eyes for each of the 3 eye locations. Where did the light really come from as it seemed to make an image of the object candle? Can you draw the complete path for the light—from object to mirror surface to eye? Do you see any relationship between the angles of light paths from object candle to the reflecting surface and from the reflecting surface to your eye?

5. Blow out both candles. Take the Christmas-tree lights and attach them with tape to the top of one of the candles so that there is a different-colored bulb on either side of the candle top, as in figure 2. Plug the lights in, and place the candle in front of the sheet. What happens to right and left in the reflected image?

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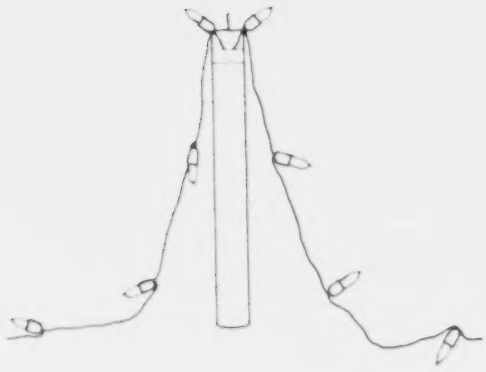

Lights attached to candle with tape

figure 2

Part B: Multiple Images in Plane Mirrors

1. Move the candle to the side and set up the second sheet of Plexiglas so that the sheets are at right angles to one another and touch along one edge, as shown in figure 3. Before you place the candle with the lights on it in front of the sheets, predict how many images you will see.

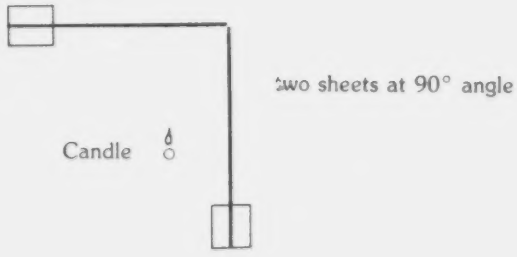

figure 3

2. Put the candle in front of the mirrors, slightly closer to one mirror than to the other. How many images do you see? Measure D_o from the object candle to the junction of the two mirrors. Place the second candle over each reflected image in turn and measure each D_i. Record these values on the Data Table. What can you say about the D_o and D_i values? What happens to left and right in each image? Why? Try to draw a complete diagram of the mirrors, one location for the candle and its images, including "lines of sight" that explain how you see each image.
3. Move the mirrors so that the angle between them is less than 90°. What happens to the location and the number of images? Continue to narrow the angle, noticing where the images move, how many there are, and what happens to left and right in each one. Measure D_o and all D_is for each new angle. Always measure to the junction of the two mirrors.

ANALYSIS:

1. What conclusion can you draw about the relation of the distance from the object to the reflecting surface and the distance from the image to the reflecting surface?
2. Were left and right reversed in the reflected image in one mirror? In the images in two mirrors at a right angle? In the images in two mirrors at narrowing angles? Can you explain why? Referring to your diagrams and notes, what is the order in which the reflections are reversed and not reversed?

OUR FINDINGS:

See Section V.

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REFRACTION AND TOTAL INTERNAL REFLECTION

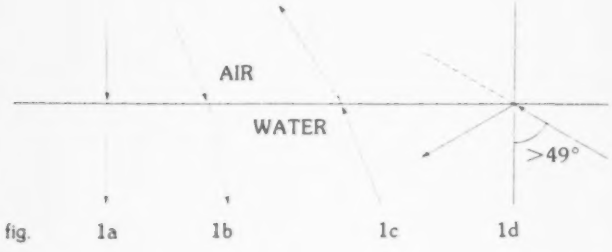
Alfred W. Guenther

TOPIC:

Refraction and Internal Reflection

INTRODUCTION:

When light rays travel from one transparent substance to another, they are *refracted* (bent). This happens as long as the light rays are not exactly perpendicular to the boundary of the two substances (see figure 1a). The direction of bending depends on the relative speed at which light travels through the different substances. For example, because light travels faster in air than in water, when a light ray enters water, it is bent toward the perpendicular (see figure 1b). When a light ray emerges from water into air (goes from a slower to a faster medium), it is bent away from the perpendicular (see figure 1c).



Light rays at a boundary of air and water. (Dashed lines show what the straight path would be.)

However, when a light ray strikes a slower-to-faster boundary at an angle to the perpendicular greater than a certain value (for water to air about 49°), instead of normal refraction, a related optic phenomenon occurs—*total internal reflection*. The light ray is completely reflected off the boundary (see figure 1d), and none of the light passes through. In this procedure, you will observe some of the effects of refraction and total internal reflection.

TIME NEEDED:

1½ hours

MATERIALS:

chewing gum
penny
styrofoam cup
water
a stack of books about 15 cm high
quarter
large clear drinking glass

PROCEDURE:

Part A. Refraction

1. For this part of the experiment, you will need the help of a partner. First, chew a small piece of gum until it is soft. Stick the penny to the gum and then use the gum to stick the penny

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to the inside bottom of the styrofoam cup. The edge of the penny should be right next to the side of the cup.

2. Set the cup on the table with the penny side farthest away from you. Rest your chin on some books about 15 cm high and move the cup away from you until the penny is just out of sight. (The edge of the cup nearest you should be just blocking your view of the penny on the bottom.) (See figure 2.)

figure 2

3. Hold your head perfectly still and have your partner slowly pour water into the cup. As the cup is filling, carefully observe what happens to the image of the penny.

Part B. Total Internal Reflection

1. Set the quarter on the table.
2. Set a large clear glass on top of the coin. Observe the coin through the side of the glass. Is the coin visible?
3. While you watch the coin through the side of the glass, fill the glass with water. What happens to the image of the coin?
4. Look over the top of the glass. Do not look at the actual coin, which should now be visible through the bottom of the glass. Instead, look at the opposite interior side of the glass. Record your observations.

ANALYSIS:

Objects are visible when light bounces off their surfaces and enters your eyes. Our brains assume that the light from the objects travels in a straight path to our eyes. Thus, we can be fooled by refraction and total internal reflection because an object appears in a certain place—or does not appear at all—only because the light rays coming from that object have been bent. For example, when you reach for a rock you see at the bottom of a shallow pond, you may come up empty-handed unless you take refraction into account. You automatically extend the light rays that reach your eyes in a straight line to the place on the bottom of the pond where the rock appears to be. But as figure 3 shows, that is not where the rock actually is. If you were farther off to the side of the rock so that your eyes were at a great enough angle to it, you would not see the rock at all, because of total internal reflection

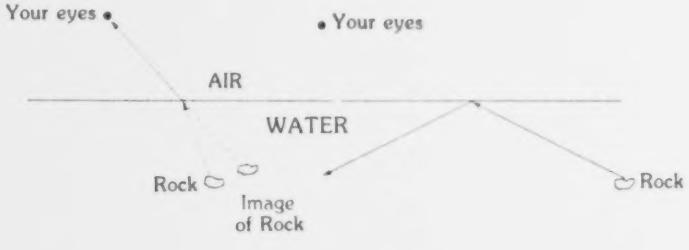

figure 3

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1. Describe what happened when the styrofoam cup was filled with water. Try to construct a diagram to explain what you saw.

2. Describe what you saw from the side and from the top of the clear glass when it was filled with water. Try to draw a diagram to explain what you saw. (Hint: The glass-air boundary is important here. The speed of light is fastest in air, much slower in water, and slowest in glass. Refraction also plays a part.)

OUR FINDINGS:

See Section V.

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THE MYSTERIOUS BLINKING NEON LIGHT

Michael G. Pearson

TOPIC:

Alternating Current

INTRODUCTION:

Most of our homes are supplied with alternating current. That is, electric current that reverses its direction at periodic intervals. When the current has made one trip back and forth, it has completed one cycle. The directional changes are so quick that our eyes cannot see them in time. However, our eyes can perceive them in space, as in this demonstration, in which you will also be able to calculate the number of cycles of alternating current in your electrical outlet.

TIME NEEDED:

35 minutes

MATERIALS:

12-foot electrical extension cord
120-V neon replacement bulb with resistor (can be obtained from a stereo/electronics supply store)
electrical connector caps
electrical tape
stopwatch or a clock with a second hand

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. Electricity can cause dangerous shocks. Be careful not to expose any live wires.

PROCEDURE:

1. Ask an adult who is knowledgeable about electrical current to help you set up this experiment. You will need at least one other person for the observation phase, and a group of observers is even better.
2. Cut the female plug off the end of the extension cord.
3. Split the cut end of the cord in half to produce two insulated wires about 1 inch long.
4. Strip ½ inch of insulation from each of the two wires to form leads.
5. Connect the wires of the neon bulb to the leads, using electrical connector caps as shown in the illustration.

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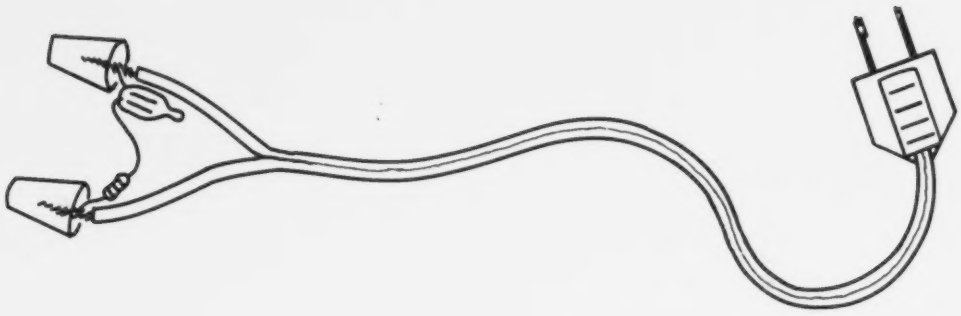

6. Use electrical tape to secure the connections, covering all exposed wires.
7. Plug the cord into a socket in a darkened room.
8. Observe the glow of the bulb without moving it. Record your observations.
9. Now find an unobstructed area in which you can swing the end of the cord so that the bulb completes a full circle. As you swing the cord, observe the bulb and record your observations. For best results, swing the cord at high speed in as large a circle as possible in a plane perpendicular to the floor.
10. While swinging the cord at a constant rate, have an observer determine the number of light flashes occurring in the full circle. The flashes will always repeat in the same positions, so you can take several trials to count them all. It may be easier to count the flashes in a quarter of the circle and then multiply this number by 4 to get the total flashes per swing. If you have a group of observers, have everyone count individually and then take an average of the results. Record this figure.
11. Swinging at the same constant speed, have a partner use a watch to keep time while you count the number of swings in 10 seconds. Divide the number of swings by ten to calculate the number of swings per second.
12. Multiply the number of swings per second by the number of light flashes per swing to calculate the number of light flashes per second. Record this figure.

ANALYSIS:

1. Why did you see flashes of light instead of a straight circle of light?
2. In an encyclopedia or your science book, look up the standard number of cycles per second in alternating current in most households. Compare this figure to the one you calculated in step 12. Can you explain why the figures compare as they do?

OUR FINDINGS:

See Section V.

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SERIES CIRCUITS

Charles Lang

TOPIC:

Series Circuits

INTRODUCTION:

Electrons flow from a point of excess to a point of deficiency in a path called an electrical circuit. There are two types of electrical circuits commonly used—series and parallel. In this demonstration, you will investigate the properties of series circuits, those in which all parts are connected one after another and current flows through each device to reach the next.

TIME NEEDED:

1½ hours

MATERIALS:

12-V lantern battery
4 12-V light bulbs
4 sockets for bulbs
hookup wire
wire cutter
wire stripper
screwdriver appropriate for sockets
ammeter
voltmeter

Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:

1. Connect three bulbs as shown in figure 1 to make a series circuit.
2. Insert the ammeter in the circuit as shown in figure 2 to determine the current in the battery. Record this value in the Data Table.
3. Insert the ammeter in the circuit as shown in figure 3 to determine the current in the first bulb. Record this value in the Data Table.
4. Repeat the procedure for the other two bulbs.
5. With a voltmeter, measure the voltage across each bulb and across the power supply. (See figures 4 and 5.) Record these values. Add a fourth bulb and measure the voltage.

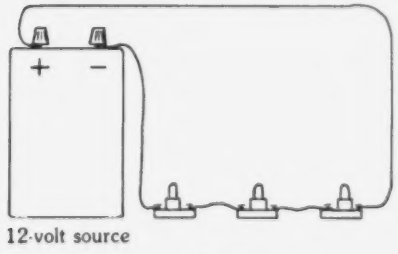

figure 1

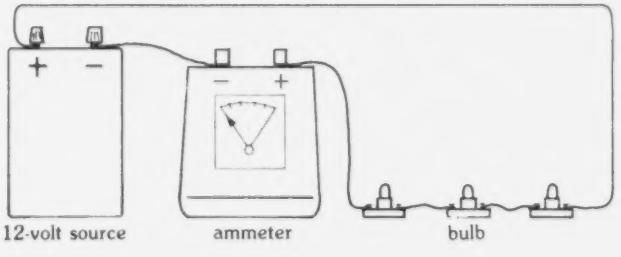

figure 2

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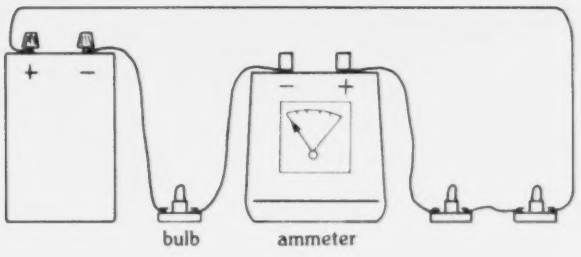

figure 3

6. Using the values obtained for voltage and current, calculate the resistance for each bulb and power of each bulb and of the power supply. Record your results on the Data Table.

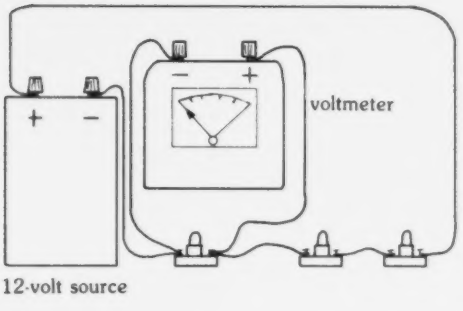

figure 4

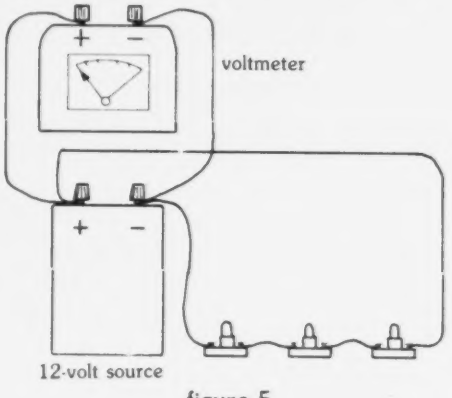

figure 5

ANALYSIS:

1. Compare the current (amperage) through each bulb and the power supply.
2. Compare the voltage across each bulb with the voltage of the power supply. What happened when you added the fourth bulb?
3. Using your analysis of resistance, what will happen to the light intensity of each light bulb in a series circuit when more lights are added to the circuit?
4. How does the power supplied by the battery compare with the power used by the three light bulbs?
5. In a string of Christmas lights connected in series, what would happen to the other light bulbs if one of the bulbs burned out?

DATA TABLE

	Current (amps)	Voltage (volts)	Resistance (ohms) ohms = volts/amps	Power (watts) watts = volts × amps
Power Supply				
Device 1				
Device 2				
Device 3				
Device 4				

OUR FINDINGS:

See Section V.

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PARALLEL CIRCUITS

Charles Lang

TOPIC:

Parallel Circuits

INTRODUCTION:

In parallel circuits, devices on the same circuit are independent of each other. Instead of current flowing through one device after another, the current divides and a part of it goes through each. In this demonstration, you will discover some of the properties of parallel circuits.

TIME NEEDED:

1½ hours

MATERIALS:

12-V lantern battery
4 12-V light bulbs
1 24-V light bulb
4 sockets for bulbs
hookup wire
wire cutter
wire stripper
screwdriver appropriate for sockets
ammeter
voltmeter

Safety Precautions

Adult supervision required. Please read and copy the safety precautions as the beginning of this book.

PROCEDURE:

1. Connect 3 bulbs as shown in figure 1 to make a parallel circuit.
2. Insert the ammeter in the circuit as shown in figure 2 to determine the current in the battery. Record this value in the Data Table.
3. Insert the ammeter in the circuit as shown in figure 3 to determine the current in the first bulb. Record this value in the Data Table.

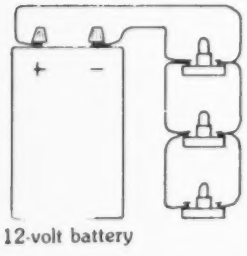

figure 1

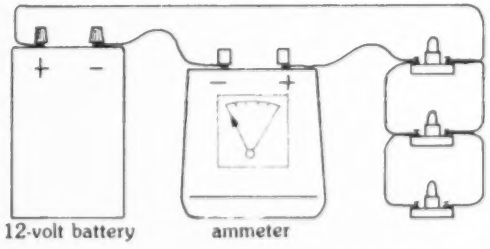

figure 2

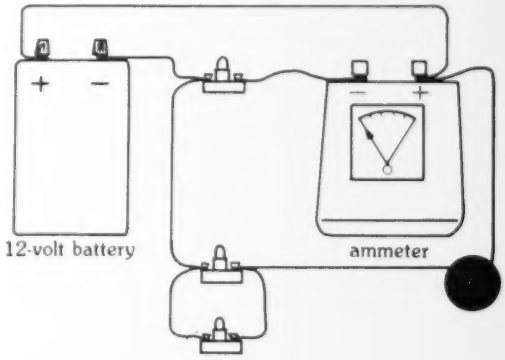

figure 3

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4. Repeat the procedure for the other two bulbs.
5. With a voltmeter, measure the voltage across each bulb and across the battery. (See figures 4 and 5.) Record these values.

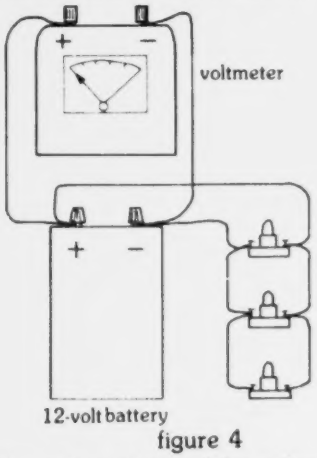

figure 4

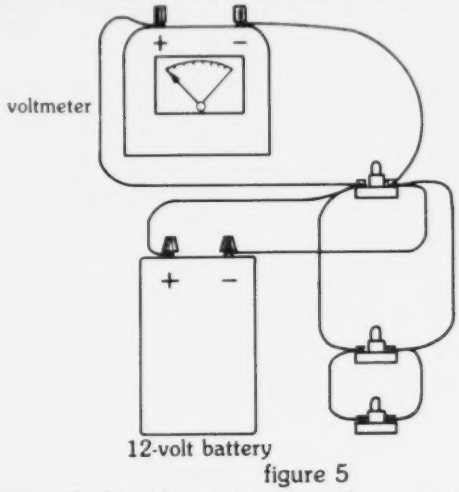

figure 5

6. Using the values obtained for voltage and current, calculate the resistance and power of each device and of the power supply. Record your results on the Data Table.

DATA TABLE

	Current (amps)	Voltage (volts)	Resistence (Ohms) ohms = volts / amps	Power (watts) watts = volts × amps
Device 1				
Device 2				
Device 3				
Battery				

7. Add a fourth bulb to the circuit and test the voltage and current. Note your results.
8. Replace one 12-V bulb with the 24-V bulb and test the voltage and current. Note your results.

ANALYSIS:

1. Compare the current (amperage) through each bulb and the battery. What happened when you replaced a 12-V bulb with a 24-V bulb?
2. Compare the voltage across each bulb with the voltage of the **battery**. What happened when you added the fourth bulb? What happened when you replaced a 12-V bulb with a 24-V bulb?
3. From your analysis of resistance, what will happen to the light intensity of each light bulb in the circuit when more lights are added?
4. How does the power supplied by the battery compare with the power used by the three light bulbs?

OUR FINDINGS:

See Section V.

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MAKING A LIGHT BULB

Connie Tiliakos

TOPIC:

Resistance

INTRODUCTION:

Resistance is any condition limiting the flow of electrons. We make use of this electrical friction in many ways. One of the most common is in the incandescent light bulb. Within the bulb is a thin wire or filament. When the light is turned on (the electrical circuit is closed), resistance builds up heat in the wire, which becomes so hot it gives off light. Several factors influence resistance, including the type, length, and thickness of the wire. In this experiment you will see how thickness affects resistance and how it can be used to produce bulbs of different brightness.

HYPOTHESIS:

The thinner the wire, the higher the resistance and the brighter the light.

TIME NEEDED:

40 minutes

MATERIALS:

ring stand with ring clamp
piece of cabled picture-hanging wire, 12 cm long
pencil
copper bell wire (or other hookup wire)
2-holed stopper
250-ml flask
12-V lantern battery
steel wool

Safety Precautions

Adult supervision required. Ask an adult who is knowledgeable about electricity to help you. Please read and copy the safety precautions at the beginning of this book. Working with electricity is potentially hazardous. Care should be taken in setting up circuits to avoid shock. When taking apart circuits, disconnect batteries first and wait for filament to cool before handling.

PROCEDURE:

1. Assemble a ring stand and ring clamp as shown in the illustration.
2. Unwind one strand of the cabled picture wire and wrap this around a pencil to make a filament.
3. Attach the ends of the filament wire to 2 pieces of hookup wire as shown in the illustration.
4. Place a 250-ml flask upside down in the ring clamp.
5. Pass the hookup wire through the holes in the stopper.
6. Darken the room.

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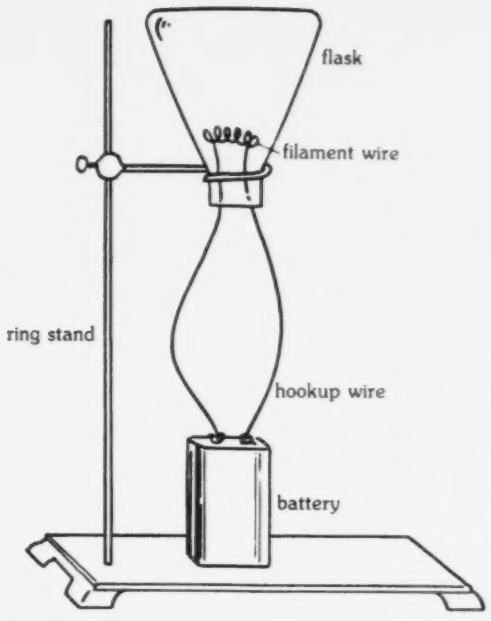

7. Put the stopper with the filament wire into the flask and attach the hookup wires to the battery.
8. Check connections if the bulb doesn't light.
9. Unwind 2 strands of the cabled wire and twist them together.
10. Detach the battery wires, wait for filament to cool, and replace the filament with the 2-strand wire. Repeat the experiment. Observe and record any changes in the light. Then repeat the experiment again, using 4 twisted strands from the wire.
11. Repeat the experiment again, using steel wool for the filament.

ANALYSIS:

1. Explain any variations you found in the brightness of the bulb as you changed the thickness of the filament wire.
2. Describe what happened to the steel wool filament. What use might such a filament serve?

OUR FINDINGS:

See Section V.

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OUR FINDINGS

I. EARTH SCIENCE

1.001 Does Your Town Have Acid Rain?

Results will vary.

1.002 How Vulnerable Are Local Waters to Chemical Pollution?

Results will vary.

1.003 Water Currents

1. Because the molecules of a substance are closer together at lower temperatures, the cold water is denser and sinks to the bottom.
2. Currents created by melting ice can be observed at the North and South Poles and in thawing lakes and ponds in spring.
3. Because molecules of a substance are further apart at higher temperatures, the hot water floats on the top of the tank. In both cases, if you left the water in the tank long enough, the water temperature would eventually become uniform and the colored water would blend completely with the tap water.
4. The salt water sinks to the bottom because it is denser than the tap water. Whenever you add something to a solution, it becomes more dense. When the salt dissolves in the water, the salt molecules take up positions in the spaces between the water molecules.
5. A natural example of water movement caused by changes in salt density is the deep current flowing out of the Mediterranean Sea into the Atlantic Ocean. The water in the Mediterranean evaporates slightly in the hot sun and becomes more salty. It sinks and flows out into the less salty Atlantic.
6. By the same general principle described in section 4, muddy water is heavier than fresh water of the same temperature. You can test this by mixing some dirt into water and running another trial.

1.004 Surface Area and Erosion

1. The 2-in. cube has a surface area of 24 sq. in. It can be divided into 8 1-in. cubes. These each have a surface area of 6 sq. in. for a combined surface area of 48 sq. in. Thus the combined surface area of the smaller cubes is twice that of the larger cube. Halving the sides of the cubes doubles the surface area.
2. The crushed sugar cube dissolves faster.
3. Crushing the sugar cube greatly increases surface area. If each particle of sugar were considered as a cube, its sides would be very small compared with the sides of the original sugar cube. We have seen that halving the side doubles surface area; crushing the large sugar cube multiplies surface area many, many times over.
4. Increasing surface area increases the rate at which a substance dissolves in water.
5. Erosion is related to the solvent effects of water. The faster the rate of dissolving, the more rapid the erosion. The greater the surface area, the faster the rate of dissolving. Thus, increased surface area tends to speed up erosion. The smaller cubes would erode faster.

1.005 Settling Rate and Layering of Various Sized Particles

The largest beads with the greatest mass should have the fastest times of descent. Accurate start

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and stop timing is the key to good data. Medium-sized beads should be next, and the smallest beads should take the longest to fall. As a result, the drop of mixed sizes should result in well-defined layers, with the largest on the bottom, medium-size in the middle, and the smallest beads in a uniform layer on top. What is a horizontal layering in the tube becomes a vertical down-current layering in the stream. The large particles travel only a short distance and fall to the bottom, close to the source; medium particles settle next, and small particles, which stay in the water longest, are carried the farthest downstream.

1.006 Can You Predict the Movement of Air?

At first the smoke stays in the bottom jar. When the jars are reversed, the smoke rises. Cold air is heavier than warm air. The molecules in cold air move more slowly and thus are closer together. Faster-moving molecules in warm air are farther apart. When cold air is beneath warm air, it will continue to move, but the cold air will remain beneath the warm air. When cold air is above warm air, the heavier cold air will sink, and the lighter warm air will rise above the cold air.

1.007 Determining the Geological Age of Rock Samples

Problem 1 = Pennsylvanian
Problem 2 = Silurian
Problem 3 = Formation 1 Silurian; Formation 2 Pennsylvanian
Problem 4 = Mississippian
Problem 5 = Range is Cretaceous to Recent. Dinosaurs possible in Cretaceous.
Problem 6 = The genus *Homo* is only 2-3 million years old. The dinosaurs have been extinct for 60 million years. No overlap! Not possible!

1.008 Licorice Stick Half-Life Dating

The ages represented by the segments on the graph are as follows: 1. 5,500 yrs. 2. 11,000 yrs. 3. 16,500 yrs. 4. 22,000 yrs. 5. 27,500 yrs. 6. 33,000 yrs. 7. 38,500 yrs. You should be able to determine the ages of the additional randomly cut lengths by placing them according to height. For the smallest pieces, it is very difficult to accurately estimate age. This reflects a real problem in half-life dating, which is most accurate between the second and fourth half-lives of an element. After the seventh or eighth half-life of a substance has been reached in a dating procedure, scientists generally begin using a different isotope with a higher percentage of radioactivity present in order to preserve accuracy.

1.009 Reconstruction of an Ancient Environment

By applying the principle of uniformitarianism, it should be obvious that marine waters once extended over Louisiana. Based on the evidence of corals and other fossils, the water depth was probably between 30 meters and 90 meters. The water temperature was subtropical to tropical. The salinity of the ocean water was approximately normal.

1.010 Make Your Own Aliens

As environmental conditions change, creatures must adapt in order to survive. Some adaptations are more efficient than others. A creature's adaptations depend on its place in the food chain.

1.011 Measuring Quartz Crystals

Although the widths of the two crystals' faces vary, the interfacial angles of crystals of the same mineral are essentially equal. This constancy is a basic mineralogical law and can be measured

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in other quartz crystals, as well as in the crystal forms of other minerals. Though their size may vary, all crystals of a specific mineral have the same characteristic shape.

1.012 Views of the Moon as Seen from Earth

The eight phases of the moon are 1.) new moon (dark), 2.) crescent moon, 3.) quarter moon, 4.) gibbous moon, 5.) full moon, 6.) gibbous moon, 7.) quarter moon, 8.) crescent moon. The moon's period of rotation and period of revolution are so close that we see only one side of the moon from the earth. We cannot always see all of the lighted side of the moon. Because of its pattern of movement, we periodically see only certain areas, or phases, of the moon. A lunar eclipse can occur during the full moon, when the moon passes into the earth's shadow. A solar eclipse can occur during the new moon, when the moon is directly in front of the sun and the earth is in the shadow cast by the moon.

1.013 Scale Model of Our Solar System

Using the scale 1 cm = 50,000 km, the solar system will not fit in an area the size of a football field. Approximately ¾ of a mile is needed.

Although it is possible to see the relative distances between the planets using a scale of 1 cm = 5,000,000 km, the planets themselves would be too small to be seen by the naked eye, and only their relative position may be marked. This further illustrates the enormous size of the solar system and how small the planets are in relation to these distances.

The planets close to the sun are smaller than those farther away because the inner planets are terrestrial in nature while the outer planets are thought to be composed largely of gases. Pluto, which is small, does not fit the pattern. It is composed of ices rather than gases.

Scale: 1 cm = 50,000 km

Object	mean diameter (km)	scale diameter (cm)	mean distance from Sun (million km)	scale distance from sun (cm)	travel time (sec.)
Sun	1,392,000	27.840			
Mercury	4,900	.098	58	1,160	193
Venus	12,100	.242	108	2,260	360
Earth	12,800	.256	150	3,000	500
Mars	6,800	.136	228	4,560	760
Jupiter	142,800	2.856	778	15,560	2,593
Saturn	120,000	2.400	1427	28,540	4,757
Uranus	51,000	1.020	2,870	57,400	9,567
Neptune	48,600	.972	4,500	90,000	15,000
Pluto	3,000	.060	5,900	118,000	19,667

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Object	mean diameter (km)	scale diameter (cm)	mean distance from sun (million km)	scale distance from Sun (cm)	travel time (sec.)
Sun	1,392,000	.2784			
Mercury	4,900	.0001	58	11.6	193
Venus	12,100	.0024	108	21.6	360
Earth	12,800	.0026	150	30.0	500
Mars	6,800	.0014	228	45.6	760
Jupiter	142,800	.0286	778	155.6	2,593
Saturn	120,000	.0240	1,427	285.4	4,757
Uranus	51,000	.0102	2,870	574.0	9,567
Neptune	48,600	.0097	4,500	900.0	15,000
Pluto	3,000	.0006	5,900	1,180.0	19,667

1.014 Skywatch

Part A

The stars appear to move westward about 15° per hour throughout the evening. Since we have outside evidence that the earth is moving, it must be rotating eastward at about 15° per hour. Note that this is the rotational speed of the earth that makes the sun also appear to move 15 degrees per hour westward.

Part B

The stars appear to move westward at about 1° per day when observed at the same time. Since it is the earth that moves, it is revolving eastward at 1° per day, which is the orbital direction and speed of the earth about the sun.

Part C

The moon appears to move westward day or night. This observed motion is caused by the daily rotation of the earth. It is not as fast as the star's motion (*Part A*) because of the moon's orbital motion about the earth.

Part D:

The moon appears to move eastward from day to day when observed at the same time. This is the only eastward relative motion of the stars or moon as observed from the earth.

II. BIOLOGY

2.001 Shaping Up a Classification Key

Keys will vary. Some will be more logically consistent and take into account more significant variations than others.

2.002 Comparing Trees

Results will vary.

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2.003 Butterfly Behavior

Results will vary.

2.004 What Do Birds Like to Eat?

Results will vary according to the location in which the experiment is conducted and the types of birds that frequent that location.

2.005 Where Do Pill Bugs Like to Live?

Since pill bugs are gill-breathers, they need a moist environment to survive. They frequently live in mulch or under logs. Therefore, the number of bugs you see on the second day will depend on environmental conditions. If conditions are dry on Day 2, you will find fewer bugs than if conditions are moist.

2.006 Discovering Tidal Pools

Conditions in tidal pools vary depending on a number of factors such as depth and distance from the waterline. For example, tidal pools close to the high-water mark will be warmer and more saline than those near the waterline because they have been exposed to the sun for a longer period. More time is available for the heat of the sun to evaporate and warm the water. The temperature of tidal pools in general is higher than that of the ocean because the sun is heating a smaller volume of water. Organisms found in tidal pools also vary with conditions.

2.007 Ecological Survey of a Marsh

Results will vary according to the age and condition of the marsh and its environs.

2.008 The Effect of Cotyledon Removal on Peanut Embryos

Cotyledon removal retards or prevents peanut germination. Although results may vary because of the quality of the peanuts, there is an evident relationship between the amount of cotyledon removed and the way the embryo develops. In the control group, group 1, close to 100% of the peanuts germinate. (This is between 18-20 peanuts.) In group 2 (25% removal), 15-18 peanuts germinate and show normal growth. In group 3 (50% removal), 12-15 germinate; some grow more slowly and some exhibit stunted growth. In group 4 (75% removal), 8-10 germinate; they grow more slowly than the other groups and show definitely stunted growth. In group 5 (100% removal), only a few grow; they exhibit very retarded growth.

2.009 The Effect of Soil pH on Plant Growth

The plants grow best between pH 7 and pH 9. The lower and higher pH levels, especially pH 3 and 11, dramatically reduce growth. Since acid rain may reduce pH levels to below 5, the experimental results suggest that it may dramatically reduce plant growth.

2.010 Study of a Duckweed Population

1. The weak fertilizer should have a positive effect on the duckweed population, resulting in the greatest reproduction.
2. The strong fertilizer will have a negative effect on the duckweed population, indicated by a continual decline in population.
3. Petri dish A served as a control for the experiments.
4. An increase in space will cause an increase of duckweed in direct proportion to the size of the container.

The effect of fertilizer runoff on aquatic plants in the farm pond will depend on the amount of fertilizer in the runoff water. If the solution is weak, it will have a positive effect. If it is strong, it will have a negative effect.

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2.011 Effect of Food Supply on Fruit Fly Density

The most important factor influencing the population of fruit flies was the amount of food. The type of fruit fly and the number of fruit flies at the beginning of the experiment did not greatly affect the final population of flies.

2.012 Make Your Own Yogurt

1. The mixture incubated at 43° C, *Trial A*, forms yogurt. In *Trial B*, the low temperature greatly slows bacterial growth and reproduction; thus no yogurt is formed. In *Trial C*, the yogurt bacteria added to the 82°C milk are killed by the high temperature, so, again, no yogurt forms during incubation. The hypothesis is correct.
2. The milk was first heated to 82°C to kill any harmful bacteria present in it before the yogurt bacteria were added. The milk was cooled to 43°C because the higher temperature kills the yogurt bacteria and thus no yogurt would be made.
3. The milk-yogurt mixture kept cool would form yogurt if you subsequently incubated it at 43°C. The yogurt bacteria in it are still alive, and in the right temperature conditions they will grow and reproduce.
4. Most of the bacteria eaten in the yogurt will be killed off during digestion, so under ordinary circumstances they will have little effect on the eater. Although there have been no conclusive studies conducted with humans, some nutritionists believe that eating yogurt may aid digestion by helping to replenish the beneficial bacteria naturally present in a person's digestive system in situations in which these have been depleted, such as after a course of antibiotics. One form of yogurt-making bacteria is routinely fed to young cattle for this purpose.
5. Since Swiss-style yogurt has no active yogurt culture (live bacteria) it will not generate additional bacteria, thus no yogurt will form at any temperature.

2.013 Vinegar and the Vinegar Eel

The pH of the solutions decreased, showing that vinegar was produced. More vinegar was produced when there was oxygen available (indicated by a lower pH). When oxygen is not available, yeast cells use up some of the sugars from the apple cider as they make alcohol. Thus, less sugar is avilable for the *Acetobacter* to make into vinegar. Generally, the pH of the oxygenated cider drops gradually until it reaches an acidity of about 2.

The number of nematodes in the experiment increased fastest when there was a very low pH, indicating a high concentration of vinegar. The increase in vinegar indicates an increase in *Acetobacter*. As the *Acetobacter* increase, there is more food for the vinegar eels and their population also increases. The vinegar concentration may not rise as quickly during the period of fastest growth of the eels, since they are rapidly consuming the *Acetobacter* that produce the vinegar. If the experiment were continued long enough, the population growth rate of the vinegar eels and *Acetobacter* would level off as they achieved a stable predator-prey relationship. The growth of the bacteria (the prey) is controlled by the eels, which consume them, and the growth of the eels (the predators) is limited by how much bacteria is available for them to consume. In an anaerobic environment, the competition for sugar by the yeast may cause a noticeable alcohol or "hard cider" odor.

2.014 Variations on a Human Face

Even though this demonstration is carried out using the most simple laws of heredity and with only a few characteristics being examined, an amazing amount of variety will be seen from offspring to offspring. Because in reality many more factors of heredity and many more characteristics are involved, the possibilities for variety are actually much greater.

2.015 The Diving Reflex

In most cases a breath hold during a simulated dive is accompanied by bradycardia, a lower than normal pulse rate. The drop may range from 5-10 beats/minute for nonathletes to 20-30

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beats/minute for athletes and experienced swimmers and divers. Although the athlete swimmer/diver's pulse rate drops more dramatically in response to the dive, it will return more rapidly to normal once emerging from the water. Through experience, the diver's body has developed more efficient adaptation. The "diving reflex" is an advantage for swimmers and divers because it allows them to maintain themselves for longer periods of time under water, and to function more efficiently in the water in general. The pulse rate measures the rate at which the person's heart is pumping. A lowered rate means that the heart is working more slowly, so the oxygen from the held breath is being used up more slowly and the entire metabolism is functioning more efficiently.

Bradycardia will result from a breath hold even if it is not done under water, but the water ensures more consistent results because the subject is not tempted to take a breath.

2.016 How Good Are Your Taste Buds?

The thresholds for the two flavors usually are different. People are generally less sensitive (have a higher threshold) to sweet than to salty flavors. However, this order as well as the degree of sensitivity varies from person to person. The sweet-sensitive tastebuds are concentrated at the tip of the tongue (diagram A in the illustration) and the salt-sensitive ones are concentrated along the tongue's sides (diagram B). Diagrams C and D show areas of concentration of sour and bitter taste receptors, respectively.

2.017 How Are the Senses of Taste and Smell Related?

Subjects are more accurate in their identifications when their noses are unblocked. Bland foods are difficult to identify regardless of condition. Smell, touch, and sight work together to enhance our sense of taste. A cold typically clogs the nasal passages, reducing the sense of smell. Since taste is partially dependent on smell, a cold can reduce the sense of taste.

2.018 The Raw Egg Mystery

Initially, the vinegar, which is a dilute solution of acetic acid, breaks down the eggshell, which is primarily composed of calcium carbonate. The bubbles you see surrounding the shell are carbon dioxide, given off during the reaction. The reaction exposes the egg membrane, which, because it is a protein, does not react with the vinegar. Once the membrane is exposed, the egg grows larger as the vinegar passes through the membrane by diffusion, moving from an area of high concentration of solvent to that of low concentration. The egg usually continues to increase in size when it is moved to tap water. Sometimes there is a decrease in size at this point or a slowing of the rate of increase because some of the acetic acid leaves the membrane. In each case the change in size is caused because of the molecules moving from greater to lesser concentration through a selectively permeable cell membrane.

2.019 How Simple Is That Sugar? Testing for Monosaccharides

1. Results will vary depending on the brands and species of foods tested and the length of time and conditions under which they have been stored. The regular cola will probably have the highest concentration of glucose—unless it is a brand sweetened only with fructose, giving a negative result. The fruit juice will probably be next highest, followed by honey, steak sauce, and possibly bread—again depending on the brand. The potato, green vegetable, and beet may or may not exhibit low concentrations of glucose. If they were taken straight from the garden, they probably will not, since these foods store their main carbohydrate energy in starches and complex sugars. However, once the foods have been picked, the complex carbohydrates begin breaking down into simple sugar components, including glucose. Milk contains the simple sugar lactose, but should give a negative reading for glucose, as should the diet cola and water.
2. Water does not contain simple sugars. It is the control for the experiment, used to establish the negative response. Because the samples are mixed with water, it is important to establish experimentally that water is not contributing to their glucose concentrations.

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3. Potatoes contain a large amount of starch. Starches are made of large chains of glucose units that the body breaks down into the disaccharide maltose. Maltose is later reduced to units of glucose which supplies energy to the body's cells.

2.020 The Great Fruit Juice Contest

Different fruit juices will have different vitamin C concentrations. When vitamin C is added drop by drop, the iodine is gradually removed from the blue-black complex. When all of the starch has been separated from the complex, the solution turns clear. Thus, there is an inverse relationship between the number of drops of juice required to reach the end point (when the solution becomes clear) and the concentration of the vitamin C in the juice. Heat will destroy vitamin C.

2.021 Dye It Yourself—Naturally!

Many natural materials make deep, richly colored dyes. Often, however, these dyes will color the fiber/fabric samples only a light shade. Different fibers/fabrics will accept color differently, with one being deeply colored while another, exposed to the same dye, has a pale color. Dyes of one color sometimes produce a completely different color on different fabrics or fibers.

2.022 How Does a Red Leaf Produce Food?

The red leaf chromatogram and the green leaf chromatogram are similar. The green bands left on the red leaf's strip show that the red leaf contains chlorophyll just as the green leaf does. Therefore, the red leaf uses chlorophyll to make food just as the green leaf does. In the red leaf the chlorophyll is masked by red pigments.

Plants possess the ability to trap the energy of sunlight and convert it into potential chemical energy. This process is called photosynthesis. All photosynthetic organisms contain green pigments called chlorophyll. Leaves appear green because chlorophyll absorbs all colors of the radiation spectrum except green, which is reflected. In some plants, like the one you used in this project; other strong pigments mask the chlorophyll. These pigments are the plant's protection against strong sunlight. In the chromatographic process, a solvent, in which chlorophyll is soluble, is allowed to pass through the plant pigment mixture on the paper by capillaric action. The dissolved substances in the mixture are carried up the strip at different rates because of their different densities and separate out as lines at different heights on the strip. The result is called a chromatogram.

2.023 Leaves Can Make Photographs

The image from the negative is transferred to the upper surface of the leaf. This occurs because the negative allows varying amounts of light to pass through its light and dark areas to reach the leaf. Wherever light passes through, photosynthesis occurs. Wherever photosynthesis occurs, starch is formed. The iodine test shows the presence of starch. Boiling the leaf in water kills the leaf's cells and prepares them for the next step—heating the leaf in alcohol, which removes its chlorophyll. This is done so that the chlorophyll will not mask the staining of the starch. Thus the iodine reveals starch at the places that were under the light areas of the negative.

2.024 Speeding Up Nature's Green Machine

The rate of photosynthesis can be measured by the amount of oxygen given off by the elodea. The increased oxygen pushes the colored water up the tube. The faster the rate of photosynthesis, the higher the colored water rises in a given time. Increasing heat or light speeds up the process. The closer the lamp, the faster the rate of photosynthesis. The trials with no lamp and a covered flask should produce very little, if any, oxygen, because the plants lack the necessary light source. Sodium bicarbonate increases the rate of photosynthesis because it is a source of carbon dioxide.

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III. PHYSICAL SCIENCE AND CHEMISTRY

3.001 Testing Powers of Observation

Results will vary. Many students will discover that they have not described fully the properties of the box and that they were unable to describe accurately what is in the box.

3.002 Seeing Invisible Colors

The primary colors (red, blue, and yellow) do not separate. All other colors separate into two or three primary colors. Most colors we see are a combination of two or three primaries.

3.003 Fingerprinting

Types of fingerprints identified will vary, but each of an individual person's fingerprints should be similar. Carbon or charcoal powder reveals prints on non-porous surfaces, such as glass, by adhering to body oils and perspiration. Iodine vapor is used on porous papers to reveal prints because the oil and perspiration on porous paper spreads out and will not leave an accurate, undistorted impression when using powder. Iodine vapor reveals prints because it reacts with the perspiration in the paper.

3.004 Creating Clay for Testing

Although the clay does not have the same texture as its components, it is a mixture rather than a compound. Using various means, you were able to test for most of the specific ingredients in the clay.

Examining the clay with a magnifying glass revealed salt crystals in the mixture.

Blotting the clay with tissue revealed the presence of oil, while the moisture you felt revealed the presence of water.

The iodine changed color only in the presence of the flour and the clay. Since iodine is an indicator for starch, this test proved that flour, which is a starch, is present in the clay.

The water was used as a control to prove that it was the chemical properties of the iodine and not its liquidity that caused the color change.

Cream of tartar is the only substance that you could not test for easily. It is inert and does not react chemically with the other materials. It is used to help the clay stick together.

3.005 Fast and Fizzy Reactions

The glass containing hot water reacts fastest; the glass with cold water slowest. In order to react, molecules must collide at a force great enough to break the chemical bonds and permit new ones to form. This reaction cannot start until the reactants have enough energy, called threshold energy. Heat generally speeds up a reaction because molecules move faster, increasing collisions. Cold slows reactions because molecules move more slowly, decreasing the incidence of collision. The crushed Alka Seltzer tablet reacts faster than the whole one because crushing the tablet increases its exposed surface area, permitting more of the material to touch the water. The smaller the size of the reacting particle, the faster the reaction.

Explosions may occur in places with a lot of coal dust or sawdust because these small particles will react faster to heat than coal or lumber.

3.006 Natural Reaction Boosters

All of the vegetables as well as the fruits contain an enzyme catalyst that will speed up the decomposition of hydrogen peroxide. Results may vary, but in general potato is the most effective

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catalyst and turnip the least effective. Increasing surface area speeds up any chemical reaction. Fresh fruits and vegetables are more effective than old ones, and newly cut ones are more effective than those with day-old cuts because enzymes decompose in air over time. Cooking also causes enzymes to decompose, so cooked samples will be less effective as catalysts. Since chemical reactions are affected by concentration, diluting the hydrogen peroxide will slow down the reaction. Repeating the experiment using the same sample twice should produce identical results because the catalyst remains unchanged in a chemical reaction.

3.007 Products of Combustion

The results observed involve a number of complex factors, including combustion of hydrocarbons and the fact that the flame goes out before all the oxygen is consumed. The following includes some of the more basic concepts.

The major products of combustion are carbon dioxide and water. Water will appear as fog on the glass surface. The gas inside the jar first expands because it is heated by the flame. As combustion continues, the approximately 20% of the trapped air that is made up of oxygen is changed into carbon dioxide, which is 30 to 40 times more soluble in water than oxygen. As the carbon dioxide dissolves in the water, the gas loses corresponding volume. Thus, the pressure inside the jar lowers, causing the surrounding water to rush in. Lacking oxygen, the candle goes out. The lighted match later placed in the jar also goes out because the oxygen has been replaced with carbon dioxide. The lime water turns cloudy when mixed with the gas in the cylinder, indicating the presence of carbon dioxide.

3.008 What Happens When Water Is Heated?

1. The food coloring disperses more rapidly in the hot water.
2. The molecules in the hot water are moving faster, more rapidly dispersing the coloring throughout the liquid.
3. When the cold water is on the bottom, the different food colorings stay in their respective jars. The molecules in the hot water are moving faster and colliding with one another, spreading them farther apart, so this water is less dense and floats on top of the cold water.
4. When the hot water is on the bottom, the colors mix. Being less dense, the expanded hot water floats up through the cold water, mixing the colors. This type of heat transfer, which involves not just molecular movement but actual circulation of the heated portions of the water, is called convection. Because it involves the actual migration of molecules from one part of the substance to another, rather than just the vibrating molecular motion that occurs in all heated substances, it only takes place in liquids and gases.

3.009 Heat Needed to Melt Ice

The heat of fusion is about 80 cal per gram of ice. A sample calculation is shown below.

$$\text{Final volume of water} = 161 \text{ ml}$$
$$\text{Temperature change} = 48.0^\circ \text{ C}$$
$$\frac{48.0^\circ \times 100 \text{ g water}}{61 \text{ g ice}} = 78.7 \text{ cal/g}$$

3.010 Ice Cream Lab

1. Both mixtures must be stirred in order to maintain a uniform temperature throughout.
2. The ice cream mixture freezes solid after approximately 20 minutes. The temperature outside the paper cup was well below 0° C, the freezing point of water. The temperature of the ice cream mixture was close to 0° C.
3. The ice cream froze because the surrounding liquid lowered the temperature to the mixture's freezing point.
4. The freezing point of water was lowered because of the addition of salt. In general, the

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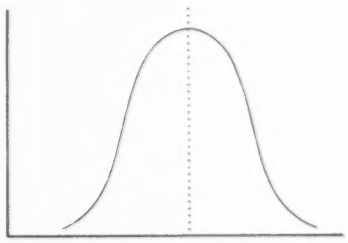
freezing point of the solution (in this case salt and water) is lower than that of a pure solvent (water). The particles of the solute (salt) fill up the spaces between the water molecules.

3.011 Coffee and Cream Science

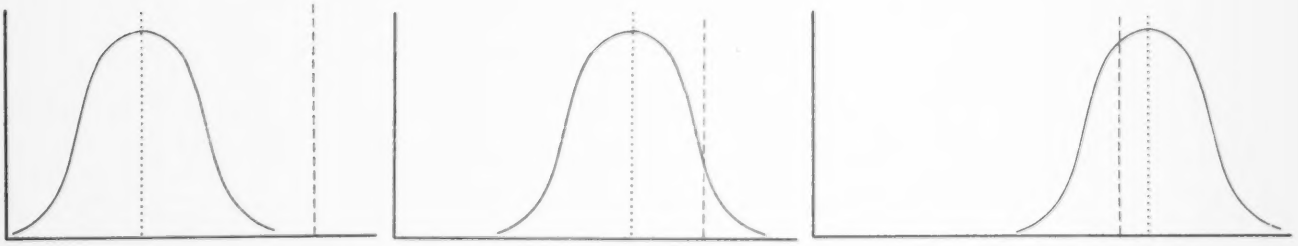
The temperature is higher at the end of the first trial, thus you should add the cream to the coffee when served if you want it to stay hot until the end of the meal. In accordance with Newton's law of cooling, the rate of cooling will be most rapid at the start of the experiment when the difference between the temperatures of the coffee and the surrounding air and cup is greatest. Adding cool cream slows the cooling rate by decreasing the difference in temperature between the hot liquid and its surroundings. Container shape and material and hot and cold volume ratio can affect cooling rate.

3.012 The Boltzmann Distribution

A Boltzmann distribution curve looks roughly like:



Corn pops because the water contained within a kernel boils and turns into water vapor, which is under pressure and explodes the kernel. As you heat the popcorn, you move the heat distribution of the kernels to hotter temperatures. As the distribution moves past the boiling point of water, first the kernels on the right end of the curve pop, and then those in the middle, and finally those at the left end, thus producing the few-many-few pattern. Imagine that the *x*-axis represented kinetic energy, with higher values as you move to the right, and that the curve represented the number of particles at each energy. Then the dotted line would correspond to the average kinetic energy, or the heat of the substance, which we would measure as temperature. If you cooled the substance, the whole curve would move to the left, indicating cooler temperature and a lower distribution of kinetic energies. If you heated the substance, the curve would move to the right.



The kinetic energy distribution moving past the boiling point of water (the dashed line)

3.013 Bubble Films and Boat Races

1. The number of actual bubble faces will always be larger than the predicted number because the soap film pulls itself into the smallest area possible. Euler's Theorem states: vertices + faces = edges + 2.

2. Open air allows more evaporation. A dry area would evaporate the bubble faster than a moist surface. The edge of a table allows greater air flow and evaporation than the center of a table. Wax paper would increase surface tension, but a newspaper would absorb liquid, decrease cohesive tension, and dry out the bubble.

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3. Hot and dry climates evaporate moisture faster than cooler, moist climates. A bubble in California might last 30 seconds, but a bubble in humid Africa could last 1-1 ½ minutes.

4. The shape of the original bubble instrument does not change the resulting bubble shape because the tension draws the liquid into a sphere. However, a large frame will elongate the shape of a bubble and make it more oval. As liquids in the bubble get pulled down by gravity, the bubble weakens at the top and becomes more wobbly.

5. The moisture on the straw adds cohesiveness to the molecules of the existing bubble. This creates a seal so the bubble does not break.

6. The cohesive forces of surface tension keep the clip afloat. Soap is an impurity that breaks the molecules apart and destroys the surface tension.

3.014 Metal Floats

Part A

1. The wood floats because its density is less than that of water. The metal sinks because its density is greater than that of water.

2. The opened metal boat floats because although metal is heavier than water, the space occupied by the opened boat has been increased so that it occupies greater volume, and more water is displaced. In terms of density, think of the boat as an object made up of the metal *and* the air that is inside it. Since air is much less dense than water, the total density of the object is less than a comparable volume of water.

Part B

1. In both trials, the weight of the water displaced should equal the weight of the boat. This demonstrates the principle of flotation: for any floating object, the weight of the water it displaces is equal to the object's weight in air. Since the apparatus you are using is not very precise, expect some experimental error—about 10-20% is not unusual.

2. If boat 2 is twice as large and made of a substance three times as light as boat 1, boat 2's weight is ⅔ that of boat 1. Therefore, because a floating object always displaces its weight in water, boat 2 displaces less water than boat 1, even though its volume is twice as great. It will float higher in the water, so that less volume is submerged and less water is displaced.

3.015 The Spectacular Siphon

Whatever the specific factors are that cause a siphon to work, we can conclude that the action of any siphon depends on the level of water at two different places.

Part A

Once the siphon has started, the water runs up one side of the tube and down the other until the water level in both containers is equal. It does not make any difference as to the length of the tubing on either side or how the containers are moved about. The only determining factor is the level of water in the two containers.

Part B

The intermittent siphon holds water until the level reaches the top of the bent tube. Once the water reaches the top of the bent tube the siphon begins to flow and empty the entire container. A toilet flushes because it is an intermittent siphon. A small amount of water can be added to a toilet bowl and nothing will happen; however, if a bucket of water is poured in, the water rises above the level of a bent pipe or passage through which the toilet drains, and the toilet will flush just as if the handle had been pulled. Since a Tantalus cup holds water until the level reaches the top of the bent tube inside the cup, at which point it drains to the bottom, it is a further example of an intermittent siphon.

Part C

Overnight, half of the water is transferred to the other container. The toilet tissue siphon behaves just like the common siphon of *Part A*, only at a much slower rate. The water levels end up being

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equal. This type of siphon relies on the capillary action in the toilet tissue to raise the water, rather than air pressure to push the water through a tube.

3.016 Boiling and Freezing a Balloon

The balloon's volume decreases in cold water and increases in steam. When the results are graphed, the zero volume point should coincide approximately with −273°. This is absolute zero on the Kelvin scale, which was designed to reflect the behavior of an ideal gas—one that behaves exactly according to the gas laws. In an ideal gas, the molecules are of negligible size and exert no force on each other.

3.017 Gases Have Their Ups and Downs

As the pressure changes in one direction, the volume changes inversely so that $P \times V$ is a constant. The value of the constant itself will vary with the amount of trapped air but is usually close to 0.02 L · atm. The precision error is usually small—around 5 percent.

3.018 Watching Atmospheric Pressure at Work

When a small amount of water is heated in the can, it forms steam. The steam pushes out the air that was in the can. When the steam-filled can is inverted into a container of cold water, however, the steam condenses, suddenly reducing the pressure within the can. Since the opening of the can is submerged, air cannot enter. The atmospheric pressure outside remains stable, but since the pressure inside drops, the pressure exerted on the can by the air outside causes the can to collapse. The amount of volume will vary depending upon specific conditions, including temperature and atmospheric pressure.

Some everyday examples in which atmospheric pressure does work are soda straws and vacuum cleaners.

3.019 Some Salts Can Be Neutralizers

Grape juice is red in acidic solutions; it is green in basic solutions; it is purple (dilute juice color) in neutral solutions. The salts that produce acidic solutions are alum and cream of tartar. The salts that produce basic solutions are baking soda, washing soda, antacids, and soap. The neutral salt solutions are table salt and epsom salts. The acidic and basic colors produced are approximately as follows:

cream of tartar—bright red
alum—reddish purple
soap—blue
baking soda—blue green
antacids—grayish green
washing soda—green

The colors you obtain from different substances may vary somewhat from the list above depending on the brands you use. The range of colors produced in the experiment indicates that the different solutions have different levels of acidity or basicity. The more red a solution, the more acidic; the more green, the more basic. A basic solution has a pH > 7. The excess $[OH^{-1}]$ came from the reaction of the negative ion with water. Example:

$$HCO_3^{-1} + HOH \rightleftarrows H_2CO_3 + OH^{-1}$$

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3.020 Flower Petal Indicators

1. The color of an extract in water provides an example of dilute extract against which to compare color changes in the acid and base solutions. Without this, it might be difficult to distinguish color changes due to reactions as indicators from color changes due to dilution.
2. Any extract whose colors are different in the base and acid solutions from its color in the water is an acid/base indictor.

3.021 Cabbage Patch Chemistry

In general, foods will be slightly to moderately acidic (lavender or pink); cosmetics will be close to neutral or slightly acidic (blue or lavender). The pH of medicines will depend on the use or type—acidic for aspirin, slightly basic for antacids, etc. Cleaning products are usually very acidic or very basic, depending on their use.

3.022 Plant Indicators for Acids and Bases

Colors of unknowns will vary, according to indicator used. The pH of vinegar ranged from 1 to 5. The pH of household ammonia ranged from 9 to 13.

3.023 What Makes a Good Conductor

1. The aluminum foil, steel wool, paper clip, copper wire, and pencil graphite all conduct electricity. The glass rod, mylar, plastic ruler, rubber tubing, charcoal stick, and wooden stick do not conduct electricity. There are only four metals among the samples: aluminum, steel (iron), nickel, and copper. Although graphite conducts electricity, it is not considered a metal. It is a form of carbon, as is charcoal—which does not conduct electricity. Carbon is one of the few elements that, in different forms, exhibits both metallic and nonmetallic properties.
2. Electrons can move through copper but not through rubber, so the copper wires are good electrical conductors and the rubber casing serves as insulation. Both conductors and insulators are necessary for electrical current to be useful. If the rubber insulation around the conducting wire were replaced by a conducting substance, current would not be directed through the wire, but would flow out uncontrollably in all directions. Air itself is a weak insulator, but rubber is a stronger one and is commonly used in an electrical apparatus.
3. None of the solid substances conducts electricity for the reasons stated in *Part C* of the procedure. The sugar has covalent bonds, and the salt and baking soda have ionic bonds that do not conduct in solid form. The salt and baking soda solutions conduct electricity. They were heated to speed up the chemical reaction, dissociation, that frees the charged particles and allows conductivity. If you test the salt water when it is cool, you will probably still observe conductivity, but it will be somewhat weaker—the bulb will not glow as brightly. Salt and baking soda are electrolytes.

3.024 Removing Silver Tarnish

1. When the tarnished silver is placed in the boiling solution, it instantly loses its dull gray coating and becomes shiny. The aluminum foil loses its shine and becomes brittle and dull gray in color.

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Aluminum loses electrons, replacing the silver in the tarnish compound and combining with the tarnish anion, sulfide, to form aluminum sulfide. This shows that aluminum is more chemically active than silver.

2. There was no change in the stainless steel or iron pot. Therefore, iron or steel must be less chemically active than aluminum, otherwise it would have combined with the sulfide, replacing silver and aluminum. You cannot tell from this procedure whether iron is more or less chemically active than silver, since as long as it is less active than aluminum it will not react. In fact, iron ranks between silver and aluminum in chemical activity. Stainless steel, composed of iron and other alloys, is designed to be resistant to corrosion and is thus relatively inactive.

3. When the aluminum replaces the silver in the tarnish to form aluminum sulfide (the dark coating visible on the aluminum), the aluminum is depleted. With enough reactions, all the aluminum would be used up. For this reason, you must periodically replace the aluminum foil in the procedure and you should never use an aluminum pot because it would be used up and destroyed by the reaction.

4. There is no reaction to the added salt. All of the silver atoms from the tarnish have remained on the original silver object. Only the sulfide ions have been removed.

3.025 The Story of Calcium

Calcium gives a positive conductivity test, showing that it is metallic. It is not very dense for a metal—1.5 g/ml—about half the density of aluminum. Calcium reacts with water fairly vigorously, giving off hydrogen gas and heat and producing insoluble calcium hydroxide (a base). Phenolphthalein indicator will turn pink or red, indicating that a base was formed. Calcium evolves approximately 2500 calories per gram in reaction with water.

3.026 The Chemical Properties of Marble

A gas is produced when an acid is added to marble or limestone. Carbon dioxide is produced when an acid is added to calcium carbonate. The calcium-carbonate solution turns pink when phenolphthalein is added, indicating basicity. When hydrochloric acid is added, the solution reacts by turning clear (yellowish). This shows that calcium carbonate is a base and it neutralizes an acid. Since an acid chemically reacts with marble (calcium carbonate), acid rain is causing marble statues, buildings, and grave markers to dissolve rapidly.

3.027 Electrographic Metal Detectors

1. Copper with ferrocyanide forms a red precipitate. Iron forms blue precipitates with both ferrocyanide and ferricyanide. Lead forms a bright yellow precipitate with chromate.

2. Galena contains lead. It forms a yellow precipitate with chromate.

3. Iron sulfide and magnetite contain iron. They form blue precipitates with both ferrocyanide and ferricyanide. Chalcocite contains copper; it forms a red precipitate with ferrocyanide.

4. Results with other samples will vary. In each case, soak the filter paper in the solution you originally used to test for the metal you are seeking. If the unknown sample delivers the same colored precipitate as the known metal sample did, the unknown contains that metal. In some cases, the precipitate that forms before the paper is rinsed will be a different color than expected. Only precipitates that remain in the paper after it is washed should be used as indicators of the metals in question.

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3.028 The Test Tube Mystery

		$AgNO_3$ 1	H_2SO_4 2	Na_2S 3	NaOH 4	NaBr 5	KI 6	HCl 7	$CuSO_4$ 8	$BaCl_2$ 9	NH_4Cl 10
$AgNO_3$	1	NLR	H_2SO_4 2								
H_2SO_4	2	NR	B→R	Na_2S 3							
Na_2S	3	$Ag_2S\downarrow$ brown–black	$H_2S\uparrow$ (egg smell) $S\downarrow$ yellow	R→B	NaOH 4						
NaOH	4	$Ag_2O\downarrow$ white	NR	NR	R→B	NaBr 5					
NaBr	5	$AgBr\downarrow$ yellow	NR	NR	NR	NLR	KI 6				
KI	6	$AgI\downarrow$ yellow	NR	NR	NR	NR	NLR	HCl 7			
HCl	7	$AgCl\downarrow$ white	NR	$H_2S\uparrow$ (egg smell)	NR	NR	NR	B→R	$CuSO_4$ 8		
$CuSO_4$	8	$Ag_2SO_4\downarrow$ white	NR	$CuS\downarrow$ brown-black	$Cu(OH)_2\downarrow$ blue	NR	$CuI\downarrow$ $I_2\downarrow$ yellow	NR	NLR	$BaCl_2$ 9	
$BaCl_2$	9	$AgCl\downarrow$ white	$BaSO_4\downarrow$ white	$BaS\downarrow$ white	$Ba(OH)_2\downarrow$ white	NR	NR	NR	$BaSO_4\downarrow$ white	NLR	NH_4Cl 10
NH_4Cl	10	$AgCl\downarrow$ white	NR	NR	$NH_3\uparrow$ (R→B)	NR	NR	NR	NR	NR	NLR

↓ = precipitate formed
↑ = gas formed
NR = no reaction
NLR = no litmus reaction

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1. silver nitrate $AgNO_3$
2. sulfuric acid H_2SO_4
3. sodium sulfide Na_2S
4. sodium hydroxide NaOH
5. sodium bromide NaBr
6. potassium iodide KI
7. hydrochloric acid HCl
8. copper sulfate $CuSO_4$
9. barium chloride $BaCl_2$
10. ammonium chloride NH_4Cl

Formulas

(3,1) $Na_2S + 2AgNO_3 \rightarrow Ag_2S + 2Na^+ + 2NO_3^-$
(4,1) $2NaOH + 2AgNO_3 \rightarrow Ag_2O + 2NaNO_3 + H_2O$
(5,1) $NaBr + AgNO_3 \rightarrow AgBr + Na^+ + NO_3^-$
(6,1) $KI + AgNO_3 \rightarrow AgI + K^+ + NO_3^-$
(7,1) $HCl + AgNO_3 \rightarrow AgCl + H^+ + NO_3^-$
(8,1) $CuSO_4 + 2AgNO_3 \rightarrow Ag_2SO_4 + Cu^{++} + 2NO_3^-$
(9,1) $BaCl_2 + 2AgNO_3 \rightarrow 2AgCl + Ba^{++} + 2NO_3^-$
(10,1) $NH_4Cl + AgNO_3 \rightarrow AgCl + NH_4^+ + NO_3^-$
(3,2) $Na_2S + H_2SO_4 \rightarrow H_2S + 2Na^+ + SO_4^-$
$+ 2H_2SO_4 \rightarrow S + H_2SO_3 + H_2O + 2Na^+ + SO_4^-$
(9,2) $BaCl_2 + H_2SO_4 \rightarrow BaSO_4 + 2Cl^- + 2H^+$
(7,3) $2HCl + Na_2S \rightarrow H_2S + 2Na^+ + 2Cl^-$
(8,3) $CuSO_4 + Na_2S \rightarrow CuS + SO_4^- + 2Na^+$
(9,3) $BaCl_2 + Na_2S \rightarrow BaS + 2Cl^- + 2Na^+$
(8,4) $CuSO_4 + 2NaOH \rightarrow Cu(OH)_2 + SO_4^- + 2Na^+$
(9,4) $BaCl_2 + 2NaOH \rightarrow Ba(OH)_2 + 2Cl^- + 2Na^+$
(10,4) $NH_4Cl + NaOH \rightarrow NH_3 + H_2O + Na^+ + Cl^-$
(8,6) $2CuSO_4 + 4KI \rightarrow 2CuI + 4K^+ + 2SO_4^- + I_2$
(9,8) $BaCl_2 + CuSO_4 \rightarrow BaSO_4 + Cu^{++} + 2Cl^-$

NOTE: (3,2) and (8,6) give two results on table. (3,2) requires two equations to explain the results. (8,6) gives both results in one equation.

3.029 Electrical Charges in Colloidal Solutions

An electric current will cause a boundary to be produced between the dark-colored and light-colored portion of the liquid. The movement of the boundary toward the negative electrode indicates that the colored iron (III) hydroxide colloidal particles are positively charged.

IV. PHYSICS

4.001 Uniform Motion

1. The toys exhibit uniform motion if they travel approximately the same distance in each time interval. Due to measuring errors, the toys' distances recorded on your Data Table will probably

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vary somewhat. Therefore the speeds will also vary somewhat.

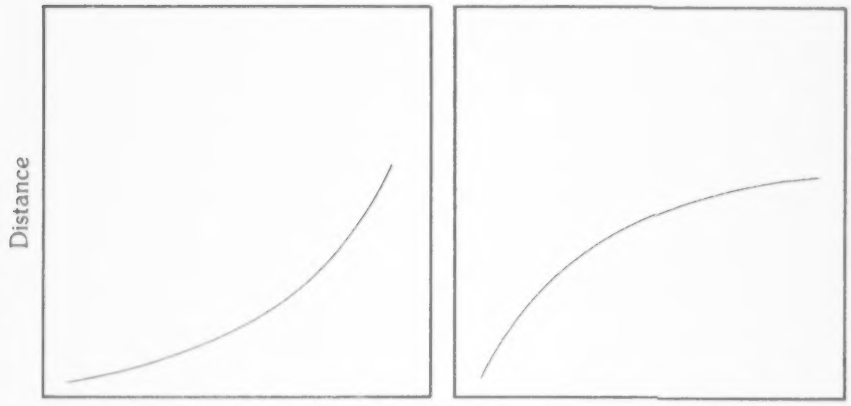
2. The sample graph (and your graph if your toys have approximately uniform motion) shows points that can almost be connected with straight lines. Straight lines are the graphic representation of uniform motion.

3. The toy with greater speed graphs has a steeper line, called the slope of the graph, that is, closer to the vertical axis.

4. You could also compute the toys' average speed by dividing the total distance each toy covered by the time it took, for example, 120 cm/12 sec = 10 cm/sec average speed.

5. If the toys were accelerating, they would graph as lines curving upward. If they were decelerating, they would graph as downward-curving lines.

Sample graphs



4.002 An Inuit Yoyo

1. As the corks are rising, you pump your hand downward.

2. As the corks are going down, you pump your hand upward.

3. Centripetal force keeps the corks in motion. It is center-seeking; therefore, when the corks are moving up you must exert a force downward and vice versa. When you spin an object on a string, you exert centripetal force on the object by pulling in on the string (figure 3, A). The object, however, has inertia, the tendency of a body to preserve its uniform motion in a straight line. Inertia would let the cork fly in a straight line if the string were cut (figure 3, B). The force exerted by pulling on the string causes it to veer off of the inertial course and take a curved path through space (figure 3, C). Since any change of course is a kind of acceleration, and to accelerate

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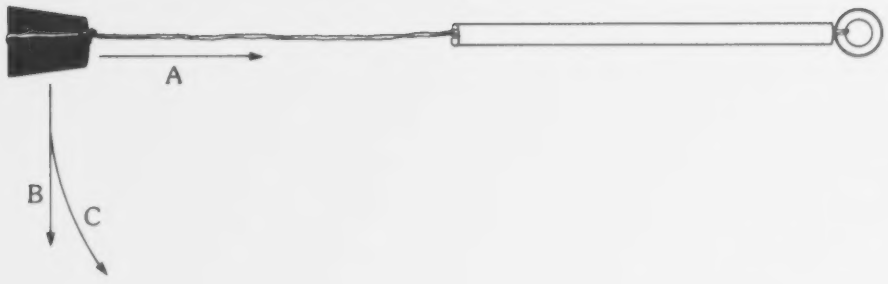

figure 3

something takes work, you feel that you are working to move the cork even though it is only going in circles. When you pump on the tube of the yoyo, you shorten the string, which in turn pulls the cork in a smaller circle. Since the cork's course is changed more when traveling in a smaller circle, the cork accelerates more in the direction of its orbit, which is necessary when the cork is rising, because gravity pulls in the opposite direction of its orbit, and decelerates it. The rhythmic pumping of the yoyo acts to counteract gravity's deceleration force.

4.003 Where Is Your Center of Gravity?

Your center of gravity is about the level of your belt or hips when standing upright with your arms by your side.

4.004 Water Rockets

The range at 45° should be the longest. At lower angles gravity tends to pull the rocket down before it has traveled very far. At higher angles, the rocket tends to go straight up and fall near its launch point. The height at 60° should be the highest. Weather conditions may cause results to vary. For example, if you found your rocket did not travel its maximum distance at 45° it may be that winds interfered with its flight, causing it to fall short of its calculated range, while at lower angles, and thus lower flying altitudes, the air may have been relatively calm, maximizing the rocket's range.

4.005 Projectiles and Gravity

Results will vary according to particular experimental conditions.

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4.006 Fighting Friction

1. Pulling the box up the inclined plane requires somewhat less force than lifting it to the same height at the top of the inclined plane.
2. More work was required to pull the box up the inclined plane because of the great increase in distance.
3. The work required to pull the skate up the inclined plane was much less than that required to pull the box because the wheels on the skate reduce friction.
4. The work needed to pull the skate up the plane was slightly less than to lift it. (For example, one experimenter found values of 1.35 joules to pull and 1.52 joules to lift.) Considering the great differences in distance, the similarity in the amount of work required to perform both tasks implies that the amount of force used has been lowered significantly. The wheels of the skate reduce friction and greatly reduce the amount of force exerted. When a wheel rolls, one point after another on the circumference comes into contact with the plane surface and then lifts off again. Thus there is little or no sliding of one surface across another—the action that produces friction.
5. Friction increases the amount of force necessary to pull an object up the inclined plane.
6. You can reduce friction in several ways: making the surface of the inclined plane smoother by covering it with wax paper or by placing rollers (round pencils or wooden dowels) under the box. If you use the second method, you must make sure to replace the dowels manually under the front of the box because they will tend to roll out behind the box. You could also secure the box to the skate.

4.007 Pitching Speed

Ball speed will vary depending on the pitcher's arm and the conditions of the individual procedure.

4.008 Behavior of the Simple Pendulum

Changing only the mass or amplitude of the pendulum did not affect the time needed for 20 swings. For the period of a simple pendulum when the amplitude is small we get

$$T = 2\pi \sqrt{l/g}$$

where

l = length of string
T = period
g = acceleration due to gravity (9.8 meters/sec^2)
π = 3.14

This equation indicates that the time for the 20 swings increases when the string is longer, but is not dependent on either the mass or the amplitude. See if your change in period due to the change in string length seems to be proportional to $\sqrt{l}$.

4.009 Clocking Speedy Sound Waves

The speed of sound in air is 331.5 meters/second at 0° C, plus 0.6 meters/second for each degree Celsius above 0°. The percentage of error in the experimental results should be about 10-15%. Windy conditions will tend to increase error. To use an accepted speed of sound to measure distance, stand some unknown distance (but at least 100 meters for good results) from a wall (or from your timing partner in *Variation A*). Take your sound timings as before. Throw out apparently distorted values. Take the air temperature and figure out the accepted speed of sound for the day. Since accepted speed = distance/time, distance = accepted speed x time. Remember to divide the result in half if you are using an echo to measure the distance to a wall. You can apply the same principles to estimate how far away lightning is in a storm. Measure the time between the lightning flash and the thunder clap and use the same formula.

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4.010 Garden Hose Bugle

1. As the horn (and the air column it contains) gets longer, the pitch gets lower. As the horn gets shorter, the pitch gets higher. While the lips vibrating in the mouthpiece produce the basic sounds (and can produce a full range of frequencies and pitches), when the mouthpiece is inserted into a particular length of hose, only certain specific notes can be supported and amplified by the resonating air column. The fundamental resonant frequency gets higher as the length of hose gets shorter, and the perceived pitch gets higher. The main effect of the funnel is to increase the volume of the sound, much like a cheerleader's megaphone.

2. The data should show that the frequency of the fundamental is *inversely* proportional to the length of the air column. To obtain a graph of a straight line, you could plot horn length (L) as a function of 1/frequency (1/f) with L on the vertical axis and 1/f on the horizontal. L is directly proportional to 1/f. Mathematically, this relation is written $L \propto 1/f$ or $L = k/f$ where k is some constant.

3. Wavelength (λ) is directly proportional to horn length ($\lambda \propto L$).
$V = \lambda f$. Dividing both sides by f we obtain $\lambda = V/f$. As explained above, since V is a constant this means λ is proportional to 1/f ($\lambda \propto 1/f$). As stated above, $L \propto 1/f$. So, $\lambda \propto L$.

4. The harmonics you are most likely to obtain from your horn will be notes 1 and 2 octaves above the horn's fundamental frequency note. Their frequencies will be 2 and 3 times that of the fundamental.

5. When the length of the horn is reduced by any given fraction, the difference in pitch (represented by the number of semitones difference on the reference instrument) is constant for that fraction. Since frequency varies inversely with column length, a proportional increase in length represents a proportional decrease in frequency and always lowers the pitch by the same number of semitones. There are 4 semitones between the 5/4 horn and the original and between the original and the 4/5 horn. There are 5 semitones between the 4/3 horn and the original and between the original and the 3/4 horn. The 3/2 horn is about 7 semitones lower than the original, and the original is 7 semitones higher than the 2/3 horn.

6. Frequency and horn length are inversely related. Doubling the horn length halves the frequency. The 3/2 horn has a frequency that is half that of the 3/4 horn. A proportional change in frequency always raises or lowers the pitch a constant number of semitones. The 3/2 horn should produce a fundamental frequency pitch one octave (12 semitones) below the 3/4 horn.

7. You have observed that a proportional change in horn length changes the pitch by a fixed number of semitones. Also, you know that frequency is inversely proportional to air column length, so jumps in pitch represent a fixed change in frequency. You have seen that multiplying frequency by 4/3 (by multiplying horn length by 3/4 causes the pitch to rise by 5 semitones. To generate all the notes on the piano, you could start with a horn whose resonant frequency gives a low C and repeatedly multiply frequency by 4/3 to move up the keyboard and obtain F, A#, D#, G#, C#, F#, B, E, A, D, G and then halve and double each of these frequencies to fill in the corresponding notes in the rest of the octaves. Alternatively, you could start with a horn whose fundamental resonant frequency was that of middle C and then produce horn lengths of any fraction to produce frequencies that would be that of middle C times the inverses of those fractions.

On a violin, any note within its register can be produced by making a length of string at any point. On the piano, notes are provided only at fixed intervals where the pitch increases by 1/12 of an octave. This relatively new kind of scale was developed in the 16th century. Starting from the fact that frequency doubles when pitch goes up an octave, mathematicians broke up the octave into 12 equal divisions. They reasoned that if they could find a number that when multiplied by itself 12 times yielded $2(\sqrt[12]{2})$, this number would provide the size of the interval between 12 equally spaced notes within an octave. 1.059 raised to the 12th power = 2, so, the frequency of any note in this system is approximately 1.06 times the frequency of the previous note. If you used a piano as your reference instrument, you were using an instrument tuned to this newer system, known as "equal temperament," instead of the tuning system of harmonic proportions that you were developing with the garden hose bugles.

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4.011 Roy G. Biv

1. If you observed all the wavelengths on the strip you would have seen 10 red, 20 green, and 30 blue. Time will vary.
2. The frequency of each color will be the number of wavelengths observed divided by the time in seconds.
3. The red wavelength is two times the green wavelength and three times the blue wavelength. The frequencies of the waves will vary depending on the value you are using for time; however, the relationships among them will always be the same: the red frequency is one-half the green frequency and one-third the blue frequency. Red has the lowest frequency and longest wavelength; blue has the highest frequency and shortest wavelength; and green is in between.
4. In waves with the same velocity, there is an inverse relationship between wavelength and frequency, that is, the longer the wavelength the lower the frequency, or the shorter the wavelength the higher the frequency.
5. Velocity = distance/time. So, the Velocity of the waves = 60 in./time (in seconds) for all the waves. Divide by the number of seconds to put your results in inches per second.
6. The products of all three multiplications will be the same. The values used for frequency will vary depending on the value being used for time. However, regardless of these variations, in all three cases multiplying the wavelength by the frequency will produce the same answer. The results will also equal the velocity of the waves that you calculated above.
7. Velocity = wavelength × frequency.

4.012 Images Formed by Plane Mirrors

The candle placed over the reflected image will always appear perfectly aligned with the image, no matter from what angle you view it. The distance from the first candle to the Plexiglas and the distance from the second candle (reflection of the first candle) to the Plexiglas are equal, but the measurement must be made to the reflecting (front) surface. This will be true no matter where the first candle is placed. This is an example of the law of reflection that states that a reflected image will always appear as far behind the mirror as the object is in front of the mirror. Your diagram of the candle and reflection will vary somewhat according to the positions of the candle and the viewer, but it should always show the same basic relationships among object, reflection, mirror, and viewer as in figure 4. In particular, the angle between the incident light ray and the mirror is always equal to the angle between the reflected ray and the mirror. Right and left are reversed in the image in the single mirror. You see three images in the mirrors at 90°. Two are reversed right and left and the third—called a "secondary image"—is not (see figure 5). This is because it is a reflection of a reflection, so it has actually been reversed twice, once in the first reflection and then again in the reflection of the reflection. In the case of mirrors less than 90° apart, the images alternate, whenever an odd number of reflections has occurred, the image is reversed; whenever an even number, the image is not reversed. The narrower the angle, the more images appear (see figure 6). D_o and D_i are equal for all angles of the mirrors. If you place the pivot point of a compass at the junction of the mirrors, and place the lead point on the object, you can draw a circle that will pass through every image. They all "stand around in a circle" whose radius is the distance from the junction of the mirrors to the object.

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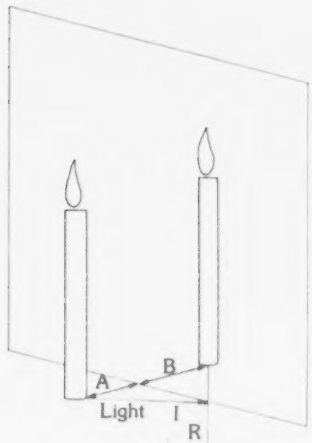
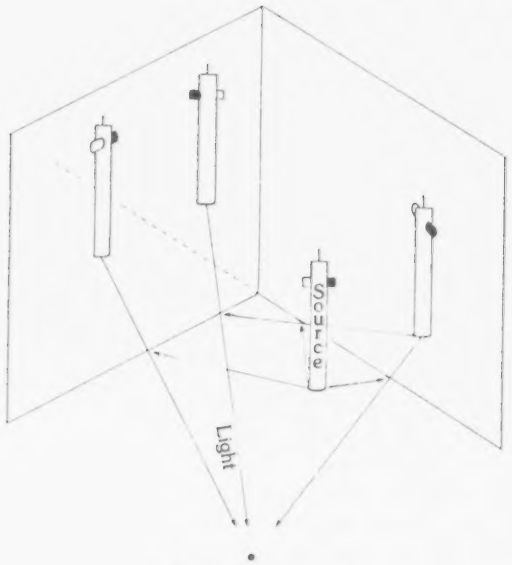


Distance A = Distance B

point of observation

Angle I (incidence) = Angle R (Reflection)

figure 4



Point of observation

figure 5

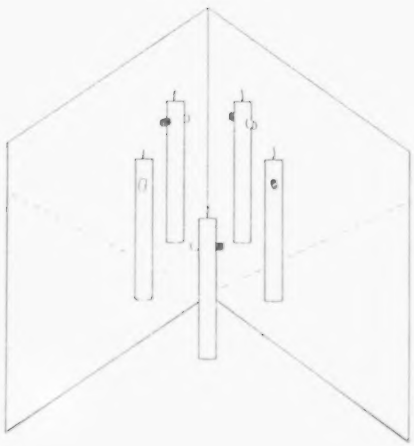


figure 6

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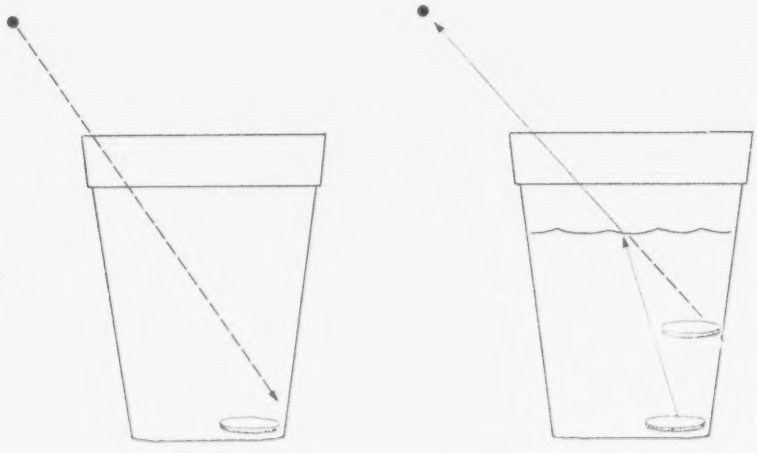
4.013 Refraction and Total Internal Reflection

1. The penny is visible once the styrofoam cup is filled with water (figure 4). Light rays coming from the coin were refracted toward the eyes at the water-air boundary (compare figure 4 with figure 1c). An image of the coin was therefore visible. As your brain assumes the light rays followed a straight path, the coin appears *higher* in the cup than it actually is.

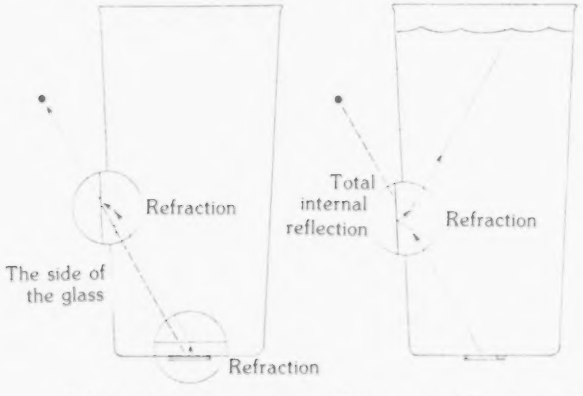


Coin blocked

figure 4

Image of coin visible because of refraction

2. The coin is clearly visible through the side of the "empty" (air-filled) glass, and it appears at the place where it actually lies—despite refraction at air-glass and glass-air boundaries (figure 5). There is air both inside and outside the glass, so the light is bent first toward the perpendicular



Coin visible in empty glass

Coin not visible in glass full of water.

figure 5

The circles in these illustrations represent magnification of the wall of the glass and illustrate how its inner and outer surfaces affect refraction and total internal reflection.

and then away from it. Since the glass is so thin—and this occurs both at the bottom of the glass and at the side—the light is only slightly deviated from its original path, and you see the coin very close to its actual position. (The dashed line in figure 5 represents your apparent line of vision.) The coin disappears when the glass is filled with water (figure 5). The light rays that travel from

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the coin through the water are first refracted at the water-glass (faster-to-slower) boundary. At the glass-air (slower-to-faster) boundary on the side of the glass, total internal reflection takes place. Thus, no light from the coin reaches your eye at this angle, and the coin is invisible. Looking over the top of the glass, you should be able to see the actual coin at the bottom and a reflected image of the coin appearing on the opposite interior side of the glass. Light rays from the coin were totally reflected at the glass-air boundary on the opposite side of the glass and then refracted toward the eye at the water-air boundary. An image of the coin was therefore visible.

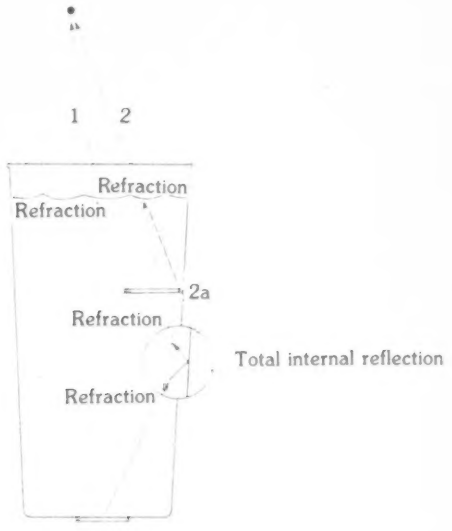
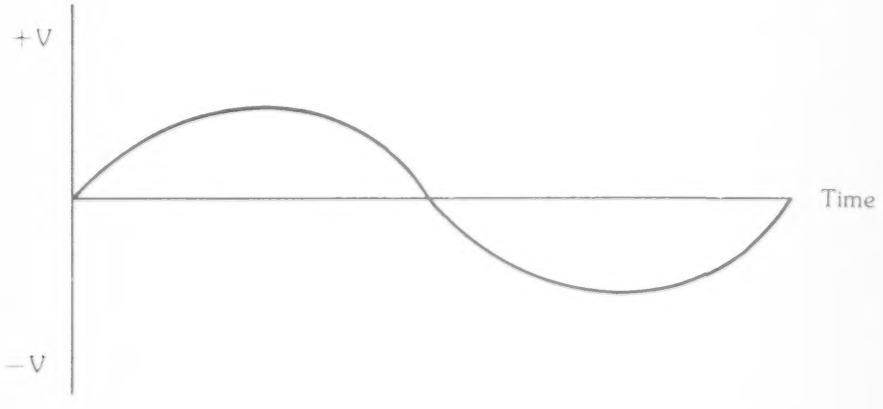


figure 6

The coin is visible from the top of the glass (path 1). An image of the coin in the opposite side is also visible (2a) because of the effects of refraction and total internal reflection (path 2).

4.014 The Mysterious Blinking Neon Light

In alternating current, the voltage, or the current it gives rise to, continuously changes the direction of flow of electrons. It can be pictured as a sine wave in which the voltage starts out at zero, then peaks at its maximum positive value before falling to its maximum negative value and then repeating itself. We see flashes of light only when the voltage approaches a peak.



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4.015 Series Circuits

1. The current is the same in all parts of the circuit.
2. In a series circuit with three bulbs, each bulb had one-third the voltage of the power supply. Adding another bulb decreased the voltage across each bulb proportionately. Each had one-fourth the voltage of the power supply. In a series with two or more loads, the voltage across each load is a fraction of the voltage supplied by the source. The sum of the voltage across each bulb is equal to the voltage supplied by the source.
3. The intensity of the bulbs decreased as more lights were added.
4. The power supplied by the battery is the sum of the power supplied to each of the bulbs.
5. If one of the lights burned out, the entire string would not light. In a series circuit, the current runs through each device. Therefore, if one device is not operational, the circuit remains open, preventing the flow of electricity.

4.016 Parallel Circuits

1. Current (amperage) to each bulb is a proportion of the total current in the power supply. Current to each bulb changes when the 24-V bulb is used, but current in all bulbs adds up to the total supplied by the power supply.
2. The voltage remains the same in all branches of the circuit regardless of the number of devices added.
3. Light intensity remains the same.
4. Power used by each bulb is a fraction of the power supplied by the lantern battery. Total power used by the bulbs equals total power supplied by the battery.

4.017 Making a Light Bulb

1. The thinnest filament glows the brightest because it has higher resistance than the thicker. You can describe the filament as a pipe through which electrons flow. Since the inside of the wire or pipe resists the flow, electrons will meet more resistance in a thin wire than a thick one because more come in contact with the inside of the wire. The resistance builds up heat to the point of incandescence.
2. The steel wool glows for the shortest time and burns out quickly. It acts in a manner similar to a fuse, melting and opening the circuit when too much current is conducted.

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GRADE LEVEL

EARTH SCIENCE

1.001	Does Your Town Have Acid Rain?	9-12
1.002	How Vulnerable Are Local Waters to Chemical Pollution?	9-12
1.003	Water Currents	6-8
1.004	Surface Area and Erosion	4-8
1.005	Settling Rate and Layering of Various Sized Particles	9-12
1.006	Can You Predict the Movement of Air?	4-8
1.007	Determining the Geological Age of Rock Samples	11-12
1.008	Licorice Stick Half-Life Dating	6-9
1.009	Reconstruction of an Ancient Environment	11-12
1.010	Make Your Own Alien	6-9
1.011	Measuring Quartz Crystals	10-12
1.012	Views of the Moon as Seen from Earth	4-8
1.013	Scale Model of our Solar System	7-12
1.014	Skywatch	7-12

BIOLOGY

2.001	Shaping Up a Classification Key	9-10
2.002	Comparing Trees	6-10
2.003	Butterfly Behavior	7-12
2.004	What Do Birds Like to Eat?	6-9
2.005	Where Do Pillbugs Like to Live?	6-9
2.006	Discovering Tidal Pools	6-9
2.007	Ecological Survey of a Marsh	9-10
2.008	The Effect of Cotyledon Removal on Peanut Embryos	4-8
2.009	The Effect of Soil pH on Plant Growth	9-10
2.010	Study of a Duckweed Population	7-12
2.011	Effect of Food Supply on Fruit Fly Density	9-10
2.012	Make Your Own Yogurt	10-12
2.013	Vinegar and the Vinegar Eel	7-12
2.014	Variations on a Human Face	9-12
2.015	The Diving Reflex	10-12
2.016	How Good Are Your Taste Buds?	9-12
2.017	How Are the Senses of Taste and Smell Related?	7-12
2.018	The Raw Egg Mystery	7-12
2.019	How Simple Is That Sugar? Testing for Monosaccharides	9-12
2.020	The Great Fruit Juice Contest	7-12
2.021	Dye It Yourself—Naturally!	6-10
2.022	How Does a Red Leaf Produce Food?	9-12
2.023	Leaves Can Make Photographs	9-12
2.024	Speeding Up Nature's Green Machine	11-12

PHYSICAL SCIENCE/CHEMISTRY

3.001	Testing Powers of Observation	7-12
3.002	Seeing Invisible Colors	7-8
3.003	Fingerprinting	6-9
3.004	Creating Clay for Testing	6-12
3.005	Fast and Fizzy Reactions	7-12
3.006	Natural Reaction Boosters	6-9
3.007	Products of Combustion	8-10

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3.008	What Happens When Water Is Heated?	4-8
3.009	Heat Needed to Melt Ice	7-12
3.010	Ice Cream Lab	6-9
3.011	Coffee and Cream Science	9-12
3.012	The Boltzmann Distribution	7-12
3.013	Bubble Films and Boat Races	3-8
3.014	Metal Floats	9-12
3.015	The Spectacular Siphon	6-8
3.016	Boiling and Freezing a Balloon	8-10
3.017	Gases Have Their Ups and Downs	10-12
3.018	Watching Atmospheric Pressure at Work	9-12
3.019	Some Salts Can Be Neutralizers	10-12
3.020	Flower Petal Indicators	7-12
3.021	Cabbage Patch Chemistry	6-12
3.022	Plant Indicators for Acids and Bases	8-10
3.023	What Makes a Good Conductor	9-12
3.024	Removing Silver Tarnish	9-12
3.025	The Story of Calcium	6-12
3.026	The Chemical Properties of Marble	7-12
3.027	Electrographic Metal Detectors	11-12
3.028	The Test Tube Mystery	10-12
3.029	Electrical Charges in Colloidal Solutions	10-12

PHYSICS

4.001	Uniform Motion	10-12
4.002	An Inuit Yoyo	6-12
4.003	Where Is Your Center of Gravity?	9-12
4.004	Water Rockets	11-12
4.005	Projectiles and Gravity	9-12
4.006	Fighting Friction	9-11
4.007	Pitching Speed	9-12
4.008	Behavior of the Simple Pendulum	7-12
4.009	Clocking Speedy Sound Waves	10-12
4.010	Garden Hose Bugle	9-12
4.011	Roy G. Biv	9-10
4.012	Images Formed by Plane Mirrors	11-12
4.013	Refraction and Total Internal Reflection	8-12
4.014	The Mysterious Blinking Neon Light	9-12
4.015	Series Circuits	10-12
4.016	Parallel Circuits	10-12
4.017	Making a Light Bulb	7-9

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SUPERVISION

ADULT SUPERVISION REQUIRED

EARTH SCIENCE

1.005 Settling Rate and Layering of Various Sized Particles
1.006 Can You Predict the Movement of Air?

BIOLOGY

2.006 Discovering Tidal Pools
2.007 Ecological Survey of a Marsh
2.009 The Effect of Soil pH on Plant Growth
2.015 The Diving Reflex
2.020 The Great Fruit Juice Contest
2.022 How Does a Red Leaf Produce Food?
2.023 Leaves Can Make Photographs

PHYSICAL SCIENCE/CHEMISTRY

3.003 Fingerprinting
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PHYSICS

4.014 The Mysterious Blinking Neon Light
4.015 Series Circuits
4.016 Parallel Circuits
4.017 Making a Light Bulb

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ADULT SUPERVISION OPTIONAL

Note: While the teachers have indicated that adult supervision is optional for these experiments, supervision is always a good idea. It is mandatory if the experiments are being done by students who, for any reason, are outside the grade level recommended.

EARTH SCIENCE

1.001 Does Your Town Have Acid Rain?
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BIOLOGY

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2.017 How Are The Senses of Taste and Smell Related?
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2.019 How Simple is That Sugar? Testing for Monosaccharides
2.021 Dye It Yourself—Naturally!
2.024 Speeding Up Nature's Green Machine

PHYSICAL SCIENCE/CHEMISTRY

3.001 Testing Powers of Observation
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3.005 Fast and Fizzy Reactions
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3.008 What Happens When Water is Heated?
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3.019 Some Salts Can Be Neutralizers
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PHYSICS

4.001 Uniform Motion
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4.007 Pitching Speed
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4.010 Garden Hose Bugle
4.011 Roy G. Biv
4.012 Images Formed by Plane Mirrors
4.013 Refraction and Total Internal Reflection

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SETTING

Note: The experiments are classified by materials used. Those under SCHOOL involve materials usually found only in science laboratories. Those with * can be performed at home with slight adaptation of such equipment as ringstands or if metric measuring containers are available. Those under HOME involve household or everyday materials. SOME EXPERIMENTS THAT CAN BE DONE AT HOME REQUIRE ADULT SUPERVISION. CONSULT THE INDIVIDUAL EXPERIMENT TO SEE IF SUPERVISION IS NECESSARY.

SCHOOL

EARTH SCIENCE

1.001 Does Your Town Have Acid Rain?
1.002 How Vulnerable Are Local Waters to Chemical Pollution?

BIOLOGY

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2.010 Study of a Duckweed Population*
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PHYSICS

4.005 Projectiles and Gravity*
4.006 Fighting Friction*
4.008 Behavior of the Simple Pendulum*
4.015 Series Circuits
4.016 Parallel Circuits
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HOME

EARTH SCIENCE

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3.007 Products of Combustion
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3.012 The Boltzmann Distribution
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3.014 Metal Floats
3.015 The Spectacular Siphon
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PHYSICS

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4.002 An Inuit Yoyo
4.003 Where Is Your Center of Gravity?
4.004 Water Rockets
4.007 Pitching Speed
4.009 Clocking Speedy Sound Waves
4.010 Garden Hose Bugle
4.011 Roy G. Biv
4.012 Images Formed by Plane Mirrors
4.013 Refraction and Total Internal Reflection
4.014 The Mysterious Blinking Neon Light

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NUMBER OF PARTICIPANTS

EXPERIMENTS THAT CAN BE DONE BY INDIVIDUALS

EARTH SCIENCE

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1.012 Views of the Moon as Seen from Earth
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3.001 Testing Powers of Observation
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3.006 Natural Reaction Boosters
3.007 Products of Combustion
3.008 What Happens When Water is Heated?
3.009 Heat Needed to Melt Ice
3.011 Coffee and Cream Science
3.012 The Boltzmann Distribution
3.013 Bubble Films and Boat Races
3.014 Metal Floats
3.015 The Spectacular Siphon
3.017 Gases Have Their Ups and Downs
3.018 Watching Atmospheric Pressure at Work
3.019 Some Salts Can be Neutralizers
3.020 Flower Petal Indicators
3.021 Cabbage Patch Chemistry
3.022 Plant Indicators for Acids and Bases
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3.024 Removing Silver Tarnish
3.025 The Story of Calcium
3.026 The Chemical Properties of Marble
3.027 Electrographic Metal Detectors
3.028 The Test Tube Mystery
3.029 Electrical Charges in Colloidal Solutions

PHYSICS

4.002 An Inuit Yoyo
4.004 Water Rockets
4.005 Projectiles and Gravity
4.006 Fighting Friction
4.008 Behavior of the Simple Pendulum
4.012 Images Formed by Plane Mirrors
4.015 Series Circuits
4.016 Parallel Circuits
4.017 Making a Light Bulb

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EXPERIMENTS REQUIRING TWO OR MORE INDIVIDUALS

BIOLOGY

2.007 Ecological Survey of a Marsh
2.014 Variations on a Human Face
2.015 The Diving Reflex
2.017 How Are the Senses of Taste and Smell Related?

PHYSICAL SCIENCE/CHEMISTRY

3.003 Fingerprinting
3.010 Ice Cream Lab
3.016 Boiling and Freezing a Balloon

PHYSICS

4.001 Uniform Motion
4.003 Where Is Your Center of Gravity?
4.007 Pitching Speed
4.009 Clocking Speedy Sound Waves
4.010 The Garden Hose Bugle
4.011 Roy G. Biv
4.013 Refraction and Total Internal Reflection
4.014 The Mysterious Blinking Neon Light

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EXPERIMENTS THAT CAN BE COMPLETED IN LESS THAN AN HOUR

EARTH SCIENCE

1.005 Settling Rate and Layering of Various Sized Particles
1.006 Can You Predict the Movement of Air?
1.007 Determining the Geologic Age of Rock Samples
1.008 Licorice Stick Half-Life Dating
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BIOLOGY

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3.012 The Boltzmann Distribution
3.013 Bubble Films and Boat Races
3.014 Metal Floats
3.015 The Spectacular Siphon (parts A & B)
3.016 Boiling and Freezing a Balloon
3.017 Gases Have Their Ups and Downs
3.018 Watching Atmospheric Pressure at Work
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PHYSICS

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4.002 An Inuit Yoyo
4.003 Where Is Your Center of Gravity?
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4.017 Making a Light Bulb

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SOME SOURCES FOR SCIENTIFIC MATERIALS AND EQUIPMENT AND AGRICULTURAL SUPPLIES

Most of the experiments in this book can be performed with materials that can be found at home or in your school's science lab, or purchased inexpensively in local stores.

In obtaining the supplies we needed to test the experiments, we developed the following short list of major suppliers of special science materials and apparatus. If there are materials called for in an experiment that are not available in your school's lab, you might ask your science teacher to order them for you from one of these companies.

Chemicals, lab apparatus and many biological supplies can only be sold to schools, professional laboratories, or qualified scientists and teachers, so you will need your science teacher's assistance in obtaining any of these items. You may be able to order seeds and plants yourself directly from the agricultural suppliers listed.

This is not a comprehensive list, and there are other reputable suppliers across the country that sell these products. The following companies are the sources that we used, and we have also included sources of information on local distributors for agricultural products.

Chemical and Biological Supplies, Geological Samples, Lab Equipment and Glassware

Carolina Biological Supply Company
2700 York Road
Burlington, NC 27215
800-334-5551

or

Box 187
Gladstone, OR 97027
800-547-1733

Fisher Scientific
Educational Materials Division
4901 W. LeMoyne Street
Chicago, IL 60651
800-621-4769

Chemicals

Sigma Chemical Company
P.O. Box 14508
St. Louis, MO 63178-9974
800-325-3010

Agricultural Supplies

W. Atlee Burpee Company
300 Park Avenue
Warminster, PA 18974
215-674-4915

Slocum Water Gardens
1101 Cypress Gardens Blvd
Winter Haven, FL 33880-6099
813-293-7151

Lilypons Water Gardens
6800 Lilypons Road
P.O. Box 10
Lilypons, MD 21717-0010
301-874-5133

Information on Local Agricultural Suppliers

US Department of Agriculture
Washington, DC
202-447-2791

National Agricultural Library
Rockville, MD
301-344-4479

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Margaret Christoph
St. Marks High School
Wilmington, Delaware

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INDEX

Acetic Acid 2.013, 3.020
Acetobacter 2.013
Acid Rain 1.001, 1.002, 2.009, 3.026
Acids 3.019, 3.020, 3.021, 3.022
Adaptation 1.010, 2.005
Amplitude 4.008
Animal Behavior 2.003, 2.004, 2.005
Ascorbic Acid 2.020
Atmospheric Pressure 3.017, 3.018

Bacteria 2.012, 2.013
Bases 3.019, 3.020, 3.021, 3.022
Birds 2.004, 2.007
Boltzmann Distribution 3.012
Bonding, Chemical 3.023
Bond Type 3.023
Boyle's Law 3.017
Bradycardia 2.015
Buffering Capacity 1.002
Butterflies 2.003

Calcium 3.025
Calcium Carbonate 3.026
Catalysts 3.006
Cell 2.018
Center of Gravity 4.003
Centripetal Force 4.002
Charles' Law 3.016
Chemical Activity 3.024
Chemical Change 3.004
Chemical Pollution 1.001, 1.002, 3.026
Chemical Reaction 3.005, 3.006, 3.025, 3.028
Chlorophyll 2.022
Chromatography 2.022, 3.002
Circuits 4.015, 4.016
Classification 2.001, 2.002
Clay 3.004
Cohesion 3.013
Colloidal Solutions 3.029
Colors 3.002
Combustion 3.007
Compounds 3.004
Conductivity 3.023, 3.025
Convection Currents 1.006, 3.008
Corrosion 3.024
Cotyledons 2.008
Crystals 1.011
Current, Alternating 4.014
Currents, Convection 1.006, 3.008
Currents, Water 1.003

Density 1.003, 3.004
Diffusion 2.018
Displacement 3.014
Drosophila Melanogaster 2.011
Duckweed 2.010
Dyes 2.021

Earth 1.012
Ecology 2.002, 2.006, 2.007, 2.010
Electrography 3.027
Electrolytes 3.023, 3.027
Electrophoresis 3.029
Embryology, Plant 2.008
Energy, Conservation of 4.007
Energy, Kinetic 3.012, 4.007
Energy, Gravitational Potential 4.007
Enzymes 3.006
Erosion 1.004
Ethology 2.003, 2.004, 2.005

Fingerprints 3.003
Fossils 1.007, 1.009
Freezing Point 3.010
Frequency 4.010, 4.011
Friction 4.006
Fruit Flies 2.011

Gases 3.016, 3.017, 3.018
Genetics 2.014
Geologic Range 1.007
Glucose 2.019
Gravity 4.003

Half-Life 1.008
Half-Life Dating 1.008
Heat 3.011
Heat of Fusion 3.009
Hydrolysis 3.019

Ice Cream 3.010
Indicators 3.020, 3.022

Layering 1.005
Light 4.011, 4.012, 4.013

Marble 3.026
Marshes 2.007
Mendel, Gregor 2.014
Metals 3.014, 3.023, 3.024, 3.025, 3.027

Microenvironments 2.013
Mirrors 4.012
Mixtures 3.004
Molecular Activity 1.003, 3.008, 3.010, 3.012
Momentum 4.007
Monosaccharides 2.019
Moon 1.012, 1.014
Motion 4.001, 4.003, 4.004, 4.005
Musical Scale 4.010

Newton's Law of Cooling 3.011

Observation, Scientific 2.001, 3.001, 3.003, 3.028
Osmosis 2.018

Paleoecology 1.009
Paper Chromatography 2.022, 3.002
Peanuts 2.008
Pendulum 4.008
Period 4.008
pH 1.001, 1.002, 2.009, 3.019, 3.021, 3.022
Photosynthesis 2.022, 2.023, 2.024
Physical Change 3.004
Pill Bugs 2.005
Pitch 4.010
Population Dynamics 2.010
Pollution 1.001, 1.002, 2.009, 3.026
Population Ecology 2.011
Pressure 3.017, 3.018
Projectiles 4.004, 4.005
Punnett Square 2.014

Rainfall 1.001
Range 4.004
Reflection 4.012, 4.013
Refraction 4.013
Resistance 4.015, 4.017

Salinity 1.003, 2.006
Salts 3.019
Sedimentary Particles 1.005
Settling Rate 1.005
Siphons 3.015
Smell 2.017
Solar System 1.013
Sound, Speed of 4.009
Sound Waves 4.009, 4.010
Stars 1.014
Succession 2.007
Sugars 2.019
Surface Area 1.004, 3.005
Surface Tension 3.013

Taste 2.016, 2.017
Temperature 1.003, 2.012, 3.005, 3.011, 3.012, 3.016
Tidal Pools 2.006
Torque 4.003
Traits 2.014
Trajectory 4.004, 4.005
Trees 2.002
Turbatrix 2.013

Uniformitarianism 1.009

Vinegar 2.013
Vinegar Eels 2.013
Vitamin C 2.020

Wavelength 4.010, 4.011
Work 3.018, 4.006

Yogurt 2.012